ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

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PROJECT NO. 2 - OPERATIONS AT HIGH TEMPERATURES

Report On

Sub-Project No. 2-7 - Determination of Water and Salt Requirements for Jungle Operations

2-11 - Influence of High Temperatures Upon the Efficiency of Personnel

2-13 - Effect of Training Upon the Efficiency of Performance at High Temperatures

2-15 - Study of the Effects of Drugs and Accessory Food Factors on Efficiency of Personnel at High Temperatures

2-17 - Study of the Physiologic Effects of High Temperatures

2-19 - Study of Efficiency of Performance and Rate of Deterioration Under Conditions of Water Limitation

Project Nos. 2 (2-7, 11, 13, 15, 17, 19) 18 October 1943

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 2(2-7,11,13,15,17,19)
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18 October 1943

STUDIES OF MEN IN SIMULATED JUNGLE (HUMID) HEAT

1. PROJECT: No. 2 - Operations at High Temperatures. Sub-Projects: 2-7 - Determination of Water and Salt Requirements for Jungle Operations; 2-11 - Influence of High Temperatures Upon the Efficiency of Personnel; 2-13 - Effect of Training Upon the Efficiency of Performance at High Temperatures; 2-15 - Study of the Effects of Drugs and Accessory Food Factors on Efficiency of Personnel at High Temperatures; 2-17 - Study of the Physiologic Effects of High Temperatures; 2-19 - Study of Efficiency of Performance and Rate of Deterioration Under Conditions of Water Limitation.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 21, 1942.

b. Purpose - The purpose of these experiments was to study the behavior and performance of military personnel when exposed to the high temperature and high humidity of a simulated jungle climate. Tests were carried out under controlled conditions in the Laboratory Hot Room, in a manner similar to that employed in the previous desert studies (Results of Desert Field Study, Project 2-8, file 724.3, October 20, 1942; Partial Report on Water and Salt Requirements for Desert Operations, Project 2-6, file 333.35, November 12, 1942; Report on Studies of Men in Simulated Desert Heat, Project 2(2-11,12,13,17), file 727-2, April 3, 1943; and Final Report on Determination of Water and Salt Requirements for Desert Operations, Project 2-6, file 333.34, May 20, 1943).

2. DISCUSSION:

a. For most men, work in humid heat of the degree imposed in these experiments is at first difficult or impossible. By a process of acclimatization man adapts himself to work in the heat. He then works without subjective complaints and with little or no disturbance of bodily functions. Acclimatization appears to be a complex physiologic readjustment which cannot be adequately defined or completely determined by a few simple physiologic measurements. Nevertheless, this adaptation is accompanied by certain physiologic changes which serve as general indices of the whole process. In this report some of these physiologic changes are discussed and represented by a series of charts.

b. Three experiments dealing with acclimatization to jungle (humid) heat and utilizing a total of 55 enlisted men were carried out. These studies were initiated in March 1943 and were continued intermittently over the ensuing six (6) months. The men were in the hot room continuously for periods varying from 8 to 23 days, being permitted to leave for only two 10 minute periods daily.

c. After a review of available records of tropical climates, the temperature and humidity arbitrarily selected for this study were those which represented the most severe conditions likely to be encountered in any tropical or jungle region. The dry bulb temperature ranged from 89° to 93.5°F and the relative humidity from 90 to 100%. Details are set forth in the Appendix.

3. CONCLUSIONS:

a. Acclimatization.

(1) Soldiers exposed to jungle (moist) heat become adapted to it by a process of acclimatization which enables them to work more efficiently and with less risk of illness from heat than when first exposed. This process does not differ in its essentials from that previously described for desert (dry) heat. (See - Report on Studies of Men in Simulated Desert Heat, Project 2(2-11,12,13,17), File 727-2, Dated April 3, 1943.)

(2) The physical fitness of men and their ability to carry out tasks in humid heat can be estimated by a careful observer who knows his men and is familiar with the signs of impending or actual danger.

(3) A man acclimatized to humid or dry heat works in humid heat with a lower body temperature, lower heart rate, more stable blood pressure, less flushing of the face and less discomfort than when not acclimatized (chart 1). These physiologic measurements do not define the exact degree of acclimatization and may not be used alone to compare the state of adaptation to heat among different subjects (chart 2). The man as a whole must be evaluated; behavior and will-to-work must be taken into consideration as well as fitness and training.

(4) Acclimatization to humid heat begins with the first exposure. The rapidity of the process varies and may require from 3 to 10 days (charts 1, 2, 3).

(5) Soldiers in good physical condition acclimatize more rapidly and when acclimatized are capable of greater work output in humid heat than are men in poor physical condition (chart 4).

(6) Resting for as long as 10 days in the humid heat, with activity limited to that required for subsistence, induces only a small degree of acclimatization. Work in humid heat is necessary for full acclimatization (chart 5).

(7) When work at a reduced level is begun on first exposure to humid heat, and is increased within the tolerance of the subject, the capacity to perform a maximum amount of work in the hot environment is attained most quickly.

(8) Strenuous work on initial exposure to humid heat is not well tolerated and often will result in disability which prevents further work. This is most evident if the subject has been living in a cool environment prior to exposure. Attempting to continue such work will incapacitate many men. Those who are able to work do so inefficiently and ineffectively.

(9) Exceeding the work capacity, even to the point of heat exhaustion does not delay acclimatization or reduce the degree finally achieved, provided (a) work is discontinued before symptoms become severe; (b) water and salt deficits are corrected; and (c) work, when resumed, is within the tolerance of the soldier (chart 6).

(10) A man acclimatizes to humid heat more rapidly if he has been living and working in a warm environment (summer - Fort Knox) than if he enters the hot environment from a cool one (late winter and early spring - Fort Knox) (charts 7 and 8). Training in the southern areas of the U. S. in summer probably induces a considerable degree of adaptation to heat.

(11) After leaving the hot humid environment, the acclimatized man retains his acclimatization for varying periods depending upon the temperature into which he goes. If the environment is cool (early spring - Fort Knox) a major portion of the acclimatization is lost within three weeks; if the environment is warm (summer - Fort Knox) most of the acclimatization is still retained after six weeks (chart 9). Men in good physical condition retain their acclimatization better than men in poor physical condition.

(12) Acclimatization to hot dry (desert) environments increases the ability of men to work efficiently in hot moist (jungle) environments (chart 10). The reverse is also true but to a lesser degree (chart 11).

b. Water Requirements.

(1) Although only a fraction of the sweat is evaporated in the humid heat of the tropical environment, a high rate of sweating is maintained. As a result, man cannot work without a fairly high water intake, much of which is wasted as unevaporated sweat. In the experimental environment of this study the water (sweat) loss sustained by resting clothed men averaged 218 grams per hour; that lost by clothed men marching 2.5 miles per hour averaged from 700 to 900 grams (1 quart) per hour (chart 12).

(2) Varying the water intake did not influence the rate of water (sweat) loss in either resting or working men (charts 14 and 15). Training does not reduce the water requirements.

c. Factors Influencing Performance of Acclimatized Men.

(1) A deterioration of performance and morale was observed after the tenth day in one group of men who continued working moderately hard (walking 5 hours each day carrying 20 pound pack) every day without rest. The deterioration was characterized by a higher heart rate and rectal temperature for a standard piece of work than at the peak of acclimatization. The appearance and reactions of the men reverted toward those observed during their initial work in humid heat. This deterioration was counteracted by a short period of removal from the jungle environment (chart 13).

(2) Suddenly restricting the water intake leads to a deterioration of morale and will-to-work, reduces greatly the efficiency with which men work, decreases the total work-output and disables many men. The well acclimatized man is reduced to a condition much like that found in the unacclimatized man on first exposure to heat (chart 16).

(3) Men, even when well acclimatized, are incapable of working effectively and efficiently in humid heat if deprived of adequate rest and sleep.

(4) Alcohol has a definitely deleterious influence on performance and morale, and is incompatible with effective performance in humid heat.

d. Personal Hygiene.

Rashes and infections of the skin and fungus infections of the feet are prevalent in hot humid environments and require rigid hygienic measures in order to control them.

4. RECOMMENDATIONS:

a. Troops brought into a hot tropical or jungle theater should, when possible, have at least two weeks of acclimatization under supervision. Supervising officers and N.C.O.'s should be thoroughly familiar with the principles embodied in this report.

b. During acclimatization, graded amounts of work should be done with carefully regulated exposures during the worst periods of the day.

c. Enough water should be drunk to satisfy thirst at all times. When water intake is inadequate for their needs men lose morale and work ineffectively and inefficiently.

d. Exposure to sun should be limited to that necessary for the care and drying of the skin and clothing.

e. All personnel should be familiar with the signs and symptoms of heat exhaustion, and should be indoctrinated in methods of preventive

and emergency treatment. These have been described previously (see Report on Studies of Men in Simulated Desert Heat, Project 2(2-11,12,13,17), file 727-2, April 3, 1943).

f. All officers should realize that the daily water and salt requirements of their men are large and that these requirements approach those for men working in desert environments. (See Final Report on Determination of Water and Salt Requirements for Desert Operations, Project 2-6, file 333.34, May 20, 1943.)

g. Alcoholic beverages should be prohibited in regions of activity in tropical theaters.

h. Since rigid hygienic measures are necessary to control skin rashes and fungus infections of the feet, particular attention should be directed to care of the skin.

i. Men recently ill should not be exposed to tropical heat before they have made a complete recovery from their illness and regained good physical condition. Frequently they will have to be reacclimatized.

j. Short periods away from extremes of heat and humidity should be provided where feasible.

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2 Incl.
#1 - Appendix
A thru G
#2 - Charts
1 thru 18

APPENDIX

A. EXPERIMENTAL CONDITIONS AND PROCEDURES

1. Environment.

The choice of a suitable experimental environment was hampered by the lack of data concerning climatic conditions within jungles. Available data on tropical climates comes from weather stations in clearings, on plantations and in cities, usually on the sea coast. Here the conditions are not necessarily representative of the thick jungles where men must live and fight. The environmental conditions of this study were based on the worst reported climates on the basis that if men can live and work under such conditions, they will live and work in any jungle environment they are likely to encounter.

In the "Hot Room" the dry bulb temperature during the day (0800 hours to 1700 hours) was maintained as close to 90°F as possible, with extremes of 89°F and 93.5°F. Similarly, the wet bulb temperature was usually 89°F to 91°F with extremes of 87°F and 92°F. The relative humidity was usually 94% to 96%, but varied from a high of 100% to a low of 88%. During the night (1800 hours to 0630 hours) the dry bulb temperature varied from 78°F to 87°F (usually 84-85°F) with a relative humidity ranging from 60% to 85%. It was not possible to maintain a saturated atmosphere at night such as one finds in most jungles. Approximately one hour was required to change from day to night environment. No radiant heat was supplied. Air movement was not measured but at no time was it considerable. The men lived continuously in the hot room except for a 10 minute "clean up" in the morning and in the evening.

These studies were carried out from early spring to early autumn, beginning early in March and continuing into October, therefore, the experimental environment represented both a great and a relatively moderate change from the environment in which the subjects had been living.

2. Experimental subjects.

Fifty-five enlisted volunteers served as experimental subjects. They were of various bodily configurations, came from all parts of the United States and were in varying states of physical fitness. The age limits of the men were 19 and 33 years. All but 6 were between the ages of 19 and 24 and the average age of the group was 22.

3. Clothing.

Several types of clothing were tested on the men. Some were clothed in jungle cover-alls and jungle boots, others in khaki uniforms or

in fatigues. Observations were also made with the men wearing only cotton shorts, shoes and socks. During preliminary training the men wore regulation fatigue clothing.

4. Preliminary training.

Before entering the hot, humid environment, all men were trained out-of-doors for one week or longer. During this time they performed the same work which they were assigned later in the hot room. This accustomed the men to the work, the experimental procedures, and produced a somewhat more uniform state of physical fitness in all men.

5. Activity in the hot environment.

The men were divided into two groups:

Group I, Resting. The 8 men in the resting group were permitted to remain inactive in the hot room for from 7 to 11 days before beginning work.

Group II, Walking. Forty-seven (47) men performed work of moderate severity and long duration, walking at a standard army pace while carrying a 20 pound pack. A walk of 2-1/2 miles in 47 minutes constituted a "work-period". A rest of 13 minutes was given between successive work-periods and observations were made during this time. Unless incapacitated, men walked two (2) successive periods in the morning and three (3) in the afternoon, a total of 12-1/2 miles a day. The data and conclusions of this report are based on observations on men performing such work.

6. Food.

Regular army fare was obtained from the soldiers' mess. No record was kept of the type or the amount of food eaten. Except for the first day in the hot environment, the men ate heartily at all times.

7. Water.

Salt was added to all drinking water (final concentration 0.1%). All fluid drunk was measured and was administered according to one of three schemes: (a) as much as desired whenever wanted, (b) 300 ml at the beginning and 300 ml in the middle of each work period plus as much as desired at all other times, and (c) restricted either to 200 ml or 150 ml per hour during the working day (0600 hours to 1700 hours) and thereafter as much as desired.

8. Sleep.

Each night eight or nine hours of sleep were scheduled. Early in the experiment some men found it difficult to sleep because of disagreeable dampness, but most were able to sleep well throughout.

9. Observations made during the work periods.

a. General appearance - Continuous records were kept of the appearance of the men as they worked; their vigor, alertness, degree of sweating and flushing of the face. Symptoms occurring during work were recorded; headache, dizziness, subjective heat and complaints of gastro-enteric or cardiovascular disturbances.

b. Heart rate - At the beginning and end of each work period the heart rate was counted with the subject in both the supine and erect posture (3 minutes in each). At the end of the walking period the heart rate was counted while the subjects were marking time. Auscultation over the precordium was necessary to determine the more rapid rates.

c. Blood pressures - At the beginning and end of each work period the blood pressure was determined while the subject was both supine and erect (3 minutes in each). Change of posture was obtained by a tilt table, and less frequently, by voluntary movement of the subject.

d. Weight - At the beginning and at the end of each work period the subjects were carefully (within 5 grams) weighed. The men were naked and the sweat dried off.

e. The water intake and urine output during each work period and during each 24-hour period was recorded.

10. Skin Temperature.

By means of a radiometer the skin temperature of 6 areas of the body (cheek, chest, abdomen, palm, back of hand and calf) were determined immediately upon completing the morning's and afternoon's work periods. The subjects were supine and unclothed, but the sweat was not dried off.

11. Blood Studies.

Blood plasma chloride concentration, plasma proteins and blood hemoglobin were determined in the post absorptive state on several occasions during the control period in the cool environment and under similar circumstances at intervals after entering the "jungle" environment.

12. Urine Studies.

For one week in the control environment and as long as the men remained in the hot humid environment, the daily 24 hour urine (0600 hours to 0600 hours) was measured for volume, specific gravity, chloride concentration and 24 hour chloride excretion.

Presentation of Data

The observations are presented by a series of representative charts.

In a typical chart (see chart #1) the heart rate, rectal temperature and blood pressure are plotted in turn along the ordinates. In plotting the

blood pressure, the systolic pressure is represented by the higher line, the diastolic pressure by the lower. Along the abscissae are indicated in order,. the day of work, the environment in which the work was performed and the work-period at the end of which the plotted data were obtained. Points vertically above each other represent measurements made at the end of the same work-period. The space between adjacent vertical lines represents one day. When single points appear for a day only the data obtained at the end of the indicated work period (usually the last) of the day are plotted. When more than one point appears within a day's lines, the data of all of the work periods indicated are plotted in turn and the number of points also indicates the number of work periods. A key with each chart interprets the type of line connecting the points, indicates whether the plotted data are for individual subjects or the averages for several men and points out pertinent circumstances under which the data were obtained.

Consider a typical chart (chart 1). The heart rate, rectal temperature and blood pressure at the end of each of the five work periods on the last day in the cool environment are plotted to the left of the double vertical line which indicates entry from the cool into the jungle environment. The first series of points to the right of this line indicates similar determinations at the end of each of the four work periods on the first day in jungle heat. Then in turn the data at the end of each work period on the second day, the third day, and so on.

Studies were made on all men in both the supine and erect postures. In this report the observations, charts and conclusions are for men in the erect posture unless otherwise specifically indicated. This decision was made because the erect posture places an added strain on the circulation of man and may reveal disturbances not otherwise apparent.

B. COMPARISON OF ACCLIMATIZED AND UNACCLIMATIZED STATES

1. Physiologic changes (chart 1)

On first exposure to humid heat, the unacclimatized man works with a rapid heart rate, a high rectal temperature and an unstable blood pressure (first day, chart 1). With continued exposure and work in the heat, the same amount of work is accomplished with less increase in heart rate and rectal temperature and with less disturbance of the blood pressure (fourth and eleventh days, chart 1). At first the changes are rapid, then more slow until finally, when fully acclimatized, the pulse rate, rectal temperature and blood pressure approximate the values obtained following similar amounts of work in the cool environment.

The cardiovascular instability of the unacclimatized state becomes especially apparent when the erect posture is assumed; the heart rate becomes very rapid, the systolic blood pressure falls and the pulse pressure narrows. As a result of the low blood pressure, cerebral circulation may become so inadequate that symptoms of cerebral hypoxia and even syncope occur. These changes are associated with erect posture. On returning to the supine position the heart rate and blood pressure return toward normal, the pulse pressure widens, and symptoms of cerebral ischemia promptly disappear. In one experiment six of fifteen men were unable to stand after working on the first day in jungle heat. In these men postural hypotension was so severe that disabling symptoms or frank syncope occurred. As acclimatization progresses these physiologic disturbances, in both the supine and erect postures, markedly diminish. Acclimatized men maintain the erect stance without difficulty.

Although a low heart rate, low rectal temperature and stable blood pressure accompany acclimatization, one cannot define this process nor detect differences in the degree of acclimatization among individuals by such measurements alone. Undoubtedly a man doing a given amount of work, is less efficient and more prone to disability when his rectal temperature and heart rate are high, than when they are low. However, individual performance is influenced by many variables which are not evaluated by such simple measurements. Each man must be considered as a whole and attention should not be focussed on the rectal temperature or the heart rate alone. The man's symptoms, appearance, behavior and actual performance must receive at least equally careful consideration in evaluating his capacity to work in the heat.

This point is emphasized by chart 2, in which are plotted the changes occurring in two men during acclimatization. In both men acclimatization was accompanied by a lowering of the heart rate and rectal temperature but the levels finally reached were different in the two men. Even when fully acclimatized, (10th to 11th day) subject EIC. usually had a high rectal temperature (103°F+) on completion of the day's 5 work-periods, whereas the rectal temperature of SER. was always much lower (100°F to 100.4°F). On the other hand the heart rate of subject EIC. was low, usually 100 to 115/min, while that of SER. was high (125 to 140/min). At this time

both men were well acclimatized and completed the prescribed amount of work easily and with vigor. In neither man did the heart rate alone or the rectal temperature alone give a true concept of the capacity to perform or of the response to the work.

In most men acclimatization is accompanied by a proportionate lowering of both the heart rate and rectal temperature. However, some fully acclimatized men have not followed this pattern but have fallen into the two following groups: (1) those with high rectal temperature and low heart rates (like EIC.) and (2) those with low rectal temperature and rapid heart rate (like SER.).

2. Symptoms and signs

The acclimatized man is alert, performs his work energetically and without symptoms. The unacclimatized man working in the heat becomes dull and apathetic, performs his work poorly and may manifest to varying degrees and either singly or in combinations, the symptoms and signs of heat exhaustion. In the present experiments these symptoms and signs appeared in the following order of frequency: Symptoms (1) fatigue, (2) headache, (3) dizziness, especially when erect, (4) loss of appetite, (5) nausea, (6) abdominal distress, (7) vomiting (8) shortness of breath. Signs (1) flushing of the face and neck, (2) rapid pulse rate (140 - 200/min), (3) fever over 102°F, (4) lack of coordinated effort (clumsy, stumbling), (5) staring, glazed eyes, (6) mental disturbances (apathy, poor judgment, irritability), (7) collapse.

Of interest is the marked flushing of the face, neck and upper chest of most men when they first work in the heat. It may be accompanied by engorgement of the scleral vessels and swelling of the nasal mucous membranes, the latter giving rise to "sniffles". Edema of the hands also occurs. All of these manifestations of overfull peripheral vascular beds disappear or diminish as acclimatization develops.

C. FACTORS IN ATTAINING AND MAINTAINING ACCLIMATIZATION TO HUMID HEAT

The factors involved in attaining and maintaining acclimatization to humid heat are presented in a series of charts and it is to be understood that these charts of changes in rectal temperature, pulse rate and blood pressure are used merely as indices of the entire process of adjustment. In all instances the changes in these indices are consistent with the picture of the man as a whole. When this is not so, specific mention of the differences is made.

1. Course of acclimatization (charts 1 and 3)

The process of acclimatization is initiated by the first exposure to heat. This is illustrated in chart 1, in which are plotted observations on one subject at the end of each work period for the first 6 days and the eleventh day in humid heat. At the end of the 4th work period on the first day in jungle heat this man was unable to continue because of discomfort and exhaustion. The heart rate was very rapid, (147/min) the rectal temperature high (102.4°F), the blood pressure low (98/82 min. Hg). He was unable to stand erect because of postural hypotension. (Each syncopal episode is indicated by a small vertical arrow pointing downward toward the abscissa line.) On the second day he completed more work (5 periods) with much less discomfort but the heart rate and rectal temperature remained high and postural hypotension with syncope recurred. On the third day there was marked improvement in all respects. The sudden change of the first 3 to 4 days was followed by a more gradual improvement over the ensuing 8 days. At the end of this time his status approximated (though it did not equal) that observed during the control period in the cool environment. Even in well acclimatized men the heart rate and rectal temperature usually remained slightly above that in the cool environment.

The pattern of acclimatization is even better indicated by the averaged data for 14 men shown in chart 3.

2. Physical condition (chart 4)

Men in good physical condition generally acclimatize to heat more rapidly than men in poor condition. When acclimatized, the fit men are capable of greater work-output in the heat with fewer symptoms and less disturbance of heart rate, rectal temperature and blood pressure than are the less fit men. They continue to show the same relative superiority of performance in the heat that they did in the cool environment.

The determination of physical fitness was based on the performance of the men while they were in the cool environment. Observations were made during a standard 5 work-period day and during several fitness tests (Harvard step test, Navy step test, Army Air Forces Test and Army Ground Forces test). In the evaluation of physical fitness the already discussed factors of performance and physiologic response were both taken into consideration. Those men were considered most fit who performed the prescribed work easily and energetically, without symptoms and with the least disturbance of their heart rate, blood pressure and rectal temperature.

Chart 4 compares the course of acclimatization of a man in good physical condition (VIL.) with that of a man in poor condition (SER.). The most striking difference is in the heart rate, which is at all times lower in the more fit subject, even on the first day when subject VIL. completed 5 work periods and subject SER. only four. Except on the second day, the curves of the heart rates are parallel throughout for the two subjects. On the first day subject SER. on the completion of his fourth work period had a rectal temperature of 0.4°F higher than subject VIL. at the end of his fifth work period. Thereafter, there were no significant differences in rectal temperatures of the two men. There was a marked tendency to postural hypotension in the less fit subject, the erect posture inducing a marked fall in systolic pressure and a narrowing of the pulse pressure. In the fit subject the blood pressure was always well maintained and the pulse pressure "wide". During the early days in the heat the less fit man worked with much more distress than the fit man. When acclimatized both men worked easily and energetically, even though the physiologic response was different in the two.

3. Activity prior to and during acclimatization (chart 5)

Continuing preliminary training in the cool environment beyond that required to develop satisfactory physical fitness does not increase the capacity for work on the first day in humid heat. Resting for six (6) to ten (10) days in the humid, hot environment produces a small and measurable increase in ability to work in the heat, but the acclimatization so induced is slight. Acclimatization is achieved most rapidly by the daily performance of graded work from the outset of exposure to humid heat.

The comparative effects on subsequent acclimatization of (a) work in the heat, (b) rest in the heat and (c) continued training in a cool environment are presented in chart 5. After the same preliminary training for three groups of men, one group (E) continued to work in the temperature out-of-doors while the other two groups (C and D) entered the "jungle" environment. Group D rested in the humid heat while Group C immediately began graded work which was continued until acclimatization was achieved. This required ten days. When group C was acclimatized, the three groups were subjected on the same day (called comparison day on chart 5) to five hours of work in the hot humid environment.

The comparative behavior of the three groups on this day is indicated by the plotted averaged data for each group (chart 5). The men who had been acclimatized (Group C) worked easily and with low heart rates and rectal temperatures and normal blood pressures. In contrast, the men without any previous exposure to heat (Group E) gave no evidence of an increased ability to work in the heat as a result of their prolonged training in the cool environment. They worked with rapid heart rates and high rectal temperatures. The performance and objective findings of the men who had rested in the heat (Group D) indicated only a small degree of acclimatization. This was most apparent at the end of the last (fifth) work-period of the day. The averaged heart rate was just as rapid as in the unacclimatized group (E) but the rectal temperature was lower and fell midway between that

of the acclimatized group (C) and the unacclimatized group (E). In the resting group (D) facial flushing and undesirable symptoms of headache and fatigue were present but these were not as severe as in group E. The slight and partial degree of acclimatization induced by resting for 10 days in a humid hot environment was considerably less than that induced in men resting for 3 days in the hot, dry (desert) environment (Studies of Men in Simulated Desert Heat, Project 2(2-11,12,13,17), File 272-2, Dated April 3, 1943).

4. Strenuous work from first exposure to heat.

Continued strenuous work on first exposure to humid heat is not well tolerated. Fourteen (14) men were asked to work for five full periods (1-1/2 miles) on their first day in the hot environment. Only 5 were able to complete the task. The men who completed the full work did so with difficulty, with rapid heart rates, high rectal temperatures and a marked reduction in morale. Completing such strenuous work on first exposure does not necessarily indicate acclimatization or the ability to continue work at that pace. The acclimatized man not only finishes the prescribed work but does so easily, without symptoms and with a minimal disturbance of heat regulation and of the circulation. Maintaining very strenuous work from the outset may lead to progressive deterioration of performance. This is in contrast to the progressive improvement of men who work within the limits of their tolerance on a schedule of gradually increasing work.

5. Initial intolerance to heat (chart 6)

Intolerance to humid heat, even to the point of exhaustion or collapse, during the first days of exposure, does not retard the rate nor decrease the degree of acclimatization finally attained, provided that when such disability occurs, work is discontinued and rest, adequate water, and salt are given. This is illustrated in chart 6, which indicates the performance to two subjects for each work-period during the first six days of work in the "jungle" environment. At no time did subject GRO. experience much subjective discomfort while working in the heat. From the first, he performed the required work energetically and easily. On the first two days his rectal temperature and heart rate were moderately elevated but thereafter well controlled. The blood pressure was well maintained. On the other hand, subject COX, had a very difficult time during the first two days. He worked with difficulty and complained of fatigue, headache, nausea and dizziness. Facial flushing was marked. The heart rate was very rapid, but the rectal temperature only moderately elevated. On the completion of each of the four work periods on the first day and the first two periods on the second day he was unable to stand without collapse. This was due to profound postural hypotension (in chart 6 each syncopal episode is indicated by an arrow immediately above the abscissa line). Between work periods he lay exhausted. Rest, water and salt were given liberally.

In spite of the poor early response, subject COX. acclimatized quickly and by the third day and thereafter his performance was just as good as that of subject GRO. Both men completed the work easily and energetically with well controlled heart rates and rectal temperatures and without postural syncope.

6. Effect of Season (previous environment) on acclimatization (charts 7 and 8)

The temperature at which men have been living prior to entering the "jungle" environment influences the initial performance and the course of acclimatization to "jungle" heat. The warmer the original environment, the better the initial performance and the more rapid the attainment of final acclimatization.

In chart 7 is plotted the amount of work which each of two groups of men was able to perform on the first six days in "jungle" heat. The groups entered the humid, hot environment at different seasons of the year: Group A (6 men) in mid-March; Group B (15 men) in early August. Both groups of men had had similar preliminary training and their performance in their original environment indicated that they were comparable in physical fitness and capacity for work.

The "amount of work" performed by each group was taken as the total man-work-periods completed by the group divided by the total possible, i.e., 5x number of men in the group, expressed as a percentage value. For example, if each of six men in a group are capable of completing only 4 periods, the amount of work done by the group is $\frac{6 \times 4}{5 \times 6} \times 100 = 80\%$

Chart 7 shows that the mid summer group (b) completed 80% of the prescribed work on the first day in "jungle" heat, the mid March group (A) only 46%. The men in group B were all stopped at the end of the fourth work period. Many men at that time looked as though they could complete the final (fifth) period. On the second day and thereafter the August group completed the full (100%) work requirement without difficulty. The performance of the March group improved more slowly and the full work requirement of the group was not achieved until the fifth day.

Chart 8 is a companion chart to chart 7 and indicated the disturbance in heart rate, rectal temperature and blood pressure sustained by Groups A and B on completing the work indicated in chart 7. The curves represent the averaged data for each group at the end of the last work period finished each day by the majority of men in the group. Though the March group (A) performed considerably less work on the first days in "jungle" heat than the August group (B), nevertheless in doing that smaller amount of work group A sustained greater subjective discomfort and more marked physiologic disturbances than group B.

This is indicated by the correspondingly higher heart rates and rectal temperatures of group A on the first "jungle" day. The elevated heart rates and rectal temperatures of group A were paralleled by the poor appearance of the men, who were flushed, fatigued and so plagued by headache and dizziness that most men were unable to continue after the second work period. The heart rates and rectal temperatures of group B, in contrast, were considerably lower and most men finished in fairly good condition.

The averaged blood pressures of the two groups were not significantly different and on the first days postural hypotension with syncope on completion of work occurred in both groups of men.

With continued work in jungle heat both groups improved subjectively and objectively. However, the improvement in appearance, behavior, heart rate and rectal temperature was slower in the mid March group (A) than in the early August group (B) (chart 8).

7. Retention of acclimatization (chart 9)

After leaving the hot, humid environment acclimatization is retained for varying periods, the lengths of which depend considerably on the environment into which the acclimatized man return. When this climate is warm acclimatization is retained for longer periods than when the climate is cold. Chart 9 illustrates this point.

Although the May group (A) acclimatized more rapidly than the March group (b), both groups were well acclimatized when they left the "jungle" environment (third heavy vertical line from left); group A in late June, Group B in late March. After a lapse of 6 weeks group A returned in mid July and worked in the "jungle" heat; group B returned in mid April after a 3 weeks lapse. Chart 9 shows that group A still retained a major portion of its acclimatization after six weeks, whereas group B had lost most of its adaptation during an interval only one half as long. Not only is this evident in the much higher heart rates and rectal temperatures of group B, but also in the fewer work periods performed (3 and 4 in contrast to 5) and in the apathetic fatigued, flushed appearance of the men. The men in the summer groups (A) unanimously agreed that the work was no more difficult than it had been six weeks previously when fully acclimatized. (Group B is admittedly small but similar results were obtained in other men).

The March group (B) was re-exposed to the humid heat on the day after the first follow up re-exposure. On this second day there was marked improvement (last column on right, chart 9). The men completed five work periods without difficulty and with considerably lower rectal temperatures and heart rates than the day before. Apparently the single re-exposure, though not well tolerated, had re-induced a considerable degree of acclimatization.

After the follow-up study in mid April, the men in group B returned to their regular duties. In late July, 3 months later, five men of this group were again studied during a day's work in the "jungle" environment. At this time their performance was surprisingly good. In all respects amount of work done, subjective reactions and physiologic measurements, their performance was considerably better than at any other time except when fully acclimatized, and this they closely approached. They seemed to have acquired considerable acclimatization during the warm summer months.

In all of these studies acclimatization was retained best by those men who had remained physically fit in the interval between exposures to humid heat.

8. Cross acclimatization in hot dry and hot humid environments (chart 10 and 11)

Acclimatization to dry (desert) heat induces a substantial degree of acclimatization to moist (jungle) heat. The reverse is also true but perhaps to a lesser degree.

Chart 10 indicates the averaged performance, on their first day in "jungle" heat, of 3 men well acclimatized to simulated desert heat (120°F dry bulb temperature, relative humidity 18% to 22%) and of 6 men without previous exposure to a hot environment. In all respects, amount of work performed, subjective appearance, heart rate, rectal temperature, occurrence of postural hypotension and syncope, the desert acclimatized men were far superior.

Chart 11 indicates the performance on their first day in "desert" heat of 4 men well acclimatized to simulated "jungle" heat and of 5 men without previous exposure to hot environments. On the test day operational difficulties made it impossible to obtain a truly desert environment. The men worked in an environment much too moist for a desert - dry bulb temperature 120°F, relative humidity 26% to 29%. Nevertheless, the performance of the jungle acclimatized men was much the better. Each man completed the full work requirement without symptoms and with rectal temperatures and pulse rates which were well controlled, though higher than in the temperate and hot moist environments. The men without previous exposure to heat did very badly. One man completed only one work period, one man three work periods, two men four periods and only one man completed the required five periods. All men were exhausted. Two had postural hypotension with syncope. Their greater (and marked) disturbances in heat regulation and circulation are very apparent in the chart.

9. Suppressive, Anti-malarial therapy

In a study still in progress and at present in its seventh week, fifteen men have received atabrine dihydrochloride since their first day in the hot, humid environment. During the first week the dose was 100 mgm twice a day six days a week and thereafter 100 mgm once a day six days a week. The drug was given orally in tablet form. Thus far, the performance of these men and the course of their acclimatization has not differed in any way from the general course already described.

D. WATER REQUIREMENTS

Work in hot humid environments is accompanied by profuse sweating. Due to the low rate of evaporation of water in such environments, much of the sweat is not evaporated and runs off the body. Since the run off sweat does not cool the body it serves no purpose and constitutes a waste of water and salt. These salt and water losses are large and must be made up, if man is to continue to live and work effectively. Adequate water and salt are just as necessary for work in jungle heat as in desert heat. The magnitude of these requirements is best determined by measuring the weight (sweat) lost by men in performing prescribed tasks. In histogram form, chart 12 indicates the frequency distribution of the weight (sweat) lost by clothed men under varying circumstances in the simulated jungle environment.

Resting men, lying on cots, lost an average of 218 grams per hour, range 77 grams to 480 grams. Unacclimatized men working on the first day in humid heat lost an average of 725 grams per work period, range 290 grams to 1310 grams. When acclimatized, the same men lost slightly greater amounts of weight (sweat) per standard work period; average loss 890 grams, range 460 grams to 1405 grams.

These data apply only to clothed men in an environment where the dry bulb temperature was between 90°F and 93°F, the wet bulb temperature between 88.5°F and 91°F, and the relative humidity between 92% and 96%. The wide variation in these weight (sweat) losses appear to result from several, as yet incompletely studied and understood, factors. Among these the effect of relatively small changes in environment is probably most important. Diurnal and seasonal (previous environment) influences appear also to effect the sweat output.

E. FACTORS INFLUENCING THE PERFORMANCE OF ACCLIMATIZED MEN

1. Deterioration (chart 13)

In one experiment involving 4 men there was a definite suggestion that the performance of well acclimatized men may deteriorate if they work continuously in humid heat for long periods. This deterioration manifested itself chiefly in a lowered morale, a reduced efficiency of work, and a return of symptoms associated with the unacclimatized state. Relief from the hot environment for several days relieved this condition. The averaged data for these four men at the end of the last work period of each day are plotted in chart 13.

In late May the men entered the "jungle" environment and remained in it continuously for 23 days. Acclimatization was rapid; most of it was attained in the first four days and the maximum by the 10th day. A change then occurred. The men began to lose their morale, they complained of their work, and found it unduly fatiguing. They worked listlessly and ploddingly. Facial flushing, which had disappeared, returned and the standard work was performed with more rapid heart rates and higher rectal temperatures but with no significant change in blood pressure.

This "deterioration" appeared to be inherent in the men themselves and not due to some unnoted change in environmental conditions, which were repeatedly checked. Moreover, no similar change appeared in four men who entered the hot room ten days later and were becoming acclimatized while the group under consideration was deteriorating.

In an attempt to overcome this state the men were worked only every other day, resting in the hot environment on the alternate days. This had no beneficial effect. After the "deterioration" had persisted, and even progressed, for 13 days, the men were removed from the hot room on the 24th day (chart 13). After 4 days in the summer out-of-doors (mid June) they returned to the "jungle" environment. Their performance was now vastly improved and in all respects they worked like well acclimatized men. Their heart rates and rectal temperatures had returned to their lowest values and closely approximated those obtained under the original temperate conditions (at the left in the chart).

This is the first experiment in this Laboratory in which men have been kept continuously in a simulated jungle environment for so long a period and the first time deterioration of acclimatized men has been encountered. It is necessary to emphasize that the nature and even existence of such a condition must be proved by further study.

2. Restriction of Water Intake (charts 14, 15 and 16)

There is a belief that the drinking of water promotes sweating and that men may be trained to reduce their water requirements. In this study, sweating was independent of the water intake both for resting (chart 14) and working men (chart 15).

The weight (sweat) loss per hour of a group of 11 resting men was not significantly different whether they drank 400 ml, 200 ml, or no water during that hour (chart 14). The subject who lost 650 grams during the first hour is the same man who lost no weight during the second and third hours. These three weighings are seriously questioned. His losses during the 4th, 5th, and 6th hours were 300, 250 and 180 grams respectively.

The weight (sweat) loss of men working with a restricted water intake is as great as the weight (sweat) loss of men working with a water intake sufficient to satisfy their thirst (chart 15). Six men, well acclimatized and stabilized in their behavior in the heat, were restricted in their water intake on one day to 150 ml per hour from 0600 hours to 1800 hours. They were asked to perform the standard five work periods. The weight (sweat) loss per work period of each man and the average for the group is plotted as the open circles in chart 15. After 1800 hours and all of the next day these men rested and drank water as desired. On the following day they again worked the standard 5 periods but drank 600 ml (enough to satisfy thirst) each work period and as much as they desired at all other times. The weight (sweat) loss of this day is plotted in chart 15 as the closed circles. It is evident that both the range and the average of the sweat loss for corresponding periods is the same whether water was or was not restricted. The reduction in weight (sweat) loss during the afternoon (4th, 5th) work-periods (chart 15) was an unexplained occurrence in these experiments. Since it occurred to an equal degree whether the water intake was adequate or restricted, it is probably not related to dehydration.

Suddenly restricting the water intake of well acclimatized men causes a marked general deterioration, greatly impairs work performance and induces physiologic changes similar to those which are present when unacclimatized men work in humid heat.

Chart 16 illustrates some of these changes in the same six acclimatized men whose weight losses are indicated in chart 15. The averaged performance of these men at the close of each work period on the day when water was given as desired (600 ml/hr) is compared with similar data obtained on a day when water was restricted to 150 ml/hr. The day of water restriction and the day of water as desired are the same days as those already described under chart 15. For reference, the performance on the last day in the cool environment and on the first and an acclimatized day in the "jungle" is also plotted. The higher heart rates and rectal temperatures after each work period on the day of water restriction are obvious. Note the rise of these values with successive periods of work. The increasing vascular instability is indicated by the falling systolic blood pressure and the narrowing pulse pressure. One man had severe postural hypotension with syncope after the third work period and was unable to work after the fourth period. The deteriorated performance when water was restricted is obvious.

The chart does not show other important changes in these men. It does not show how well acclimatized men who had performed a given task easily, energetically and cheerfully are reduced to an apathetic, listless, plodding state in an attempt to finish the same task. Motivation and morale become so low that the men "don't-give-a-damn for anything" and all they wish to

do is to rest and drink. Some men are incapacitated and those who are not are incapable of working effectively, let alone fighting.

3. Effect of Small Changes in Environment (chart 17)

The environmental conditions of this study approached the critical levels of human tolerance. Under such conditions relatively small change in environment induce considerable physiologic changes which in turn alter the performance of acclimatized men.

In chart 17 are plotted the averaged observations on 15 well acclimatized men during two successive work periods on each of two widely separated days. The double, central vertical line divides the chart into the two days; the thin vertical lines into successive work periods. Psychrometric data were obtained at 15 minute intervals; heart rate, rectal temperature, and weight at the beginning and end of each work period.

On the first of these two days the relative humidity remained "constant" while the dry bulb temperature during the 4th period rose about 2° F higher than that during the third period. This increase in dry bulb temperature was associated with an increase in heart rate (115/min to 137/min), a higher rectal temperature (100.2°F to 100.7°F) and more profuse sweating (785 grams to 1306 grams). On the other day the dry bulb temperature remained "constant" while the relative humidity during the fourth period fell to 91% - 95% from a level of 95% - 100% during the third work period. This change was accompanied by a decrease in heart rate (131-min), a fall in rectal temperature (100.6°F to 100.2°F) and less profuse sweating (1248 grams to 725 grams).

The effect of such small environmental changes must be considered in evaluating the performance and physiologic changes of men working in humid heat of this degree.

4. Rest at night

Adequate rest at night is essential for good performance in humid heat, even by acclimatized men. Deprived of it, men work ineffectively and inefficiently the next day and their work performance is usually measurably worse. The loss of a night's sleep appears to be a more serious handicap at high temperatures than in ordinary environments. High humidity and heat make adequate sleep difficult and at times impossible. Even during the cooler night, the excessive moisture in clothes and sleeping equipment makes rest hard to obtain. If adequate rest is provided through the day even though sleep is lost at night, acclimatization will progress in a satisfactory manner.

5. Clothing

Men worked in the humid heat with greatest comfort, minimal symptoms and least physiologic disturbances (lowest heart rates and rectal temperatures) when they wore only cotton shorts, socks and shoes. Other clothing produced an additional load, resulting in subjective discomfort and greater physiologic disturbances. Standard amounts of work were performed with higher cardiac rates and rectal temperatures. Preliminary experiments suggest that there may be significant differences in the loads imposed and effects produced by

various types of clothing but the data are too meager to permit conclusions. The repeated wearing and laundering of fabrics suggested itself as a possible factor in the effect of clothing on performance. Most men, when properly fitted, expressed satisfaction with the jungle shoe. It held up well over the relatively short period of these experiments.

6. Alcohol

Men intentionally intoxicated with alcohol the previous night had a definitely impaired work performance the next day, particularly in the morning.

Within a two hour period beginning at 2000 hours, two men drank 250 cc of whiskey and 500 cc of beer and one man 200 cc of whiskey and 500 cc of beer. The men became quickly and acutely intoxicated, two vomited and all three became incoordinate in their movements. The next morning these men were able to complete their required work but all complained of headache, excessive fatigue and undue thirst and one subject was severely nauseated. The work was performed with faster heart rates, higher rectal temperature and greater weight (sweat) losses than on the previous day. By afternoon these effects had worn off and the performance of the men was comparable in all respects to that of the previous day.

F. ADDITIONAL STUDIES

1. Changes in skin temperature with exposure to humid heat

Skin temperature was measured at the close of the last work period in the morning and the last work period in the afternoon. On the first day in "jungle" heat the skin temperature was increased (38°C to 39°C) in the six regions of the body where it was measured. As acclimatization developed the skin temperature in these same areas decreased toward the normal. Although the temperature differed quantitatively in the different areas (highest over the cheek and palm and lowest over the calf), the direction of change during acclimatization was the same in all regions at all times. This was true whether the regions had flushed (cheek) or not flushed (calf, abdomen) during work on the first day in humid heat. The fall in skin temperature during acclimatization coincided with the decrease in rectal temperature but, when plotted against each other, the fall in skin temperature for all areas was greater than the fall in rectal temperature.

These changes in skin temperature and rectal temperature suggest that on the first day the volume of blood flowing through the peripheral (skin) vascular beds is increased and that acclimatization is accompanied by a reduction in the volume and blood flow in these beds. This in turn suggests a relaxation of vascular tonus on first exposure to the hot environment and a return of this tonus as acclimatization develops. The disappearance of the facial flush of the unacclimatized state or acclimatization develops suggests the same conclusion.

2. Changes in blood and urinary constituents (chart 18)

The effect of the profuse sweating on the water and salt content of the blood and urine was studied in ten men. The results are plotted in chart 18 which gives the averaged data for the group.

In spite of the loss of large amounts of water in the sweat there was no evidence of hemoconcentration; both plasma protein and blood hemoglobin remained normal. The plasma chloride concentration did not change significantly, indicating no depletion of body chloride. Since the level of plasma chloride observed immediately before the men entered the hot room was rather elevated, (104.8 mE/liter) the somewhat high values on the first days in the hot environment are not significant. The maintenance of normal hydration and chloride content of the blood is attributed to the replenishment of these substances by permitting the men to drink as much water (salted to a concentration of 0.1 per cent) as they desired. This amounted to 6 to 7 liters (6-7 grams of salt) per man per day. On the first day the volume of urine excreted was halved but by the third day the volume rose to the control level of one liter.

Another mechanism is instrumental in maintaining the body chloride. During the first days, due to the loss of large amounts of chloride in the

sweat, there is a sharp reduction in the amount of chloride excreted in the urine per day. The averaged 24 hour excretion for 10 men is indicated in chart 18. This reached its lowest amount (3.9 grams) on the second day and returned to the original level (8 to 10 grams) on the fourth day.

One of the factors in this return may well be a decreased chloride concentration in the sweat leading to a decreased loss of chloride through the skin. This remains as a suggestion rather than a conclusion until careful chloride balance studies accompany these observations.

The reduction in urinary excretion of chloride was not as marked as that seen under similar circumstances when men are exposed to dry (desert) heat. Under such circumstances many men eliminated less than 1 gram of chloride per day in their urine. In the present group only one man lost less than 1 gram per day.

G. MINOR MEDICAL PROBLEMS

Most men developed the skin rash, "prickly heat", soon after beginning work in humid heat. In some it became annoyingly severe. The regions most frequently and severely involved were those subjected to constant friction either by adjacent parts of the body or by the clothing, particularly the latter. Ameliorating measures consisted of keeping the body as dry as possible, washing the dirt and salt out of the clothing nightly, and powdering the involved areas or applying mildly antiseptic lotions. These measures were not always helpful. After several weeks this mild rash gave way to pyogenic folliculitis, particularly in the groins and axillae, in many men. In some there was an associated lymphadenitis. An associated epidermophyton infection occasionally rendered the groins and axillae wet, macerated, inflamed areas which actually incapacitated the subject. These lesions were quite resistant to treatment. Removal to a sunny, less humid environment quickly relieved these skin lesions.

Surprisingly, fungus infections of the feet did not present a problem. Satisfactory control was obtained by rigid enforcement of foot discipline. This consisted of compulsory nightly fungicidal foot baths, careful drying and powdering of the feet, and the issuing of clean socks each morning.

Blistering of the feet was an annoying problem. The constantly wet feet, socks and shoes were predisposing factors which led to a softened, macerated skin more easily affected by rubbing. Properly fitting foot gear is essential if this annoyance is to be avoided.

The observations in this report pertain to a simulated jungle environment which is probably more severe than that which is encountered in most jungles. This should be borne in mind when the principles of this report are translated into field and combat instructions.

CHART - I

CHANGES IN HEART RATE, RECTAL TEMPERATURE AND BLOOD PRESSURE DURING ACCLIMATIZATION TO WORK IN JUNGLE HEAT; EFFECT OF CHANGE IN POSTURE

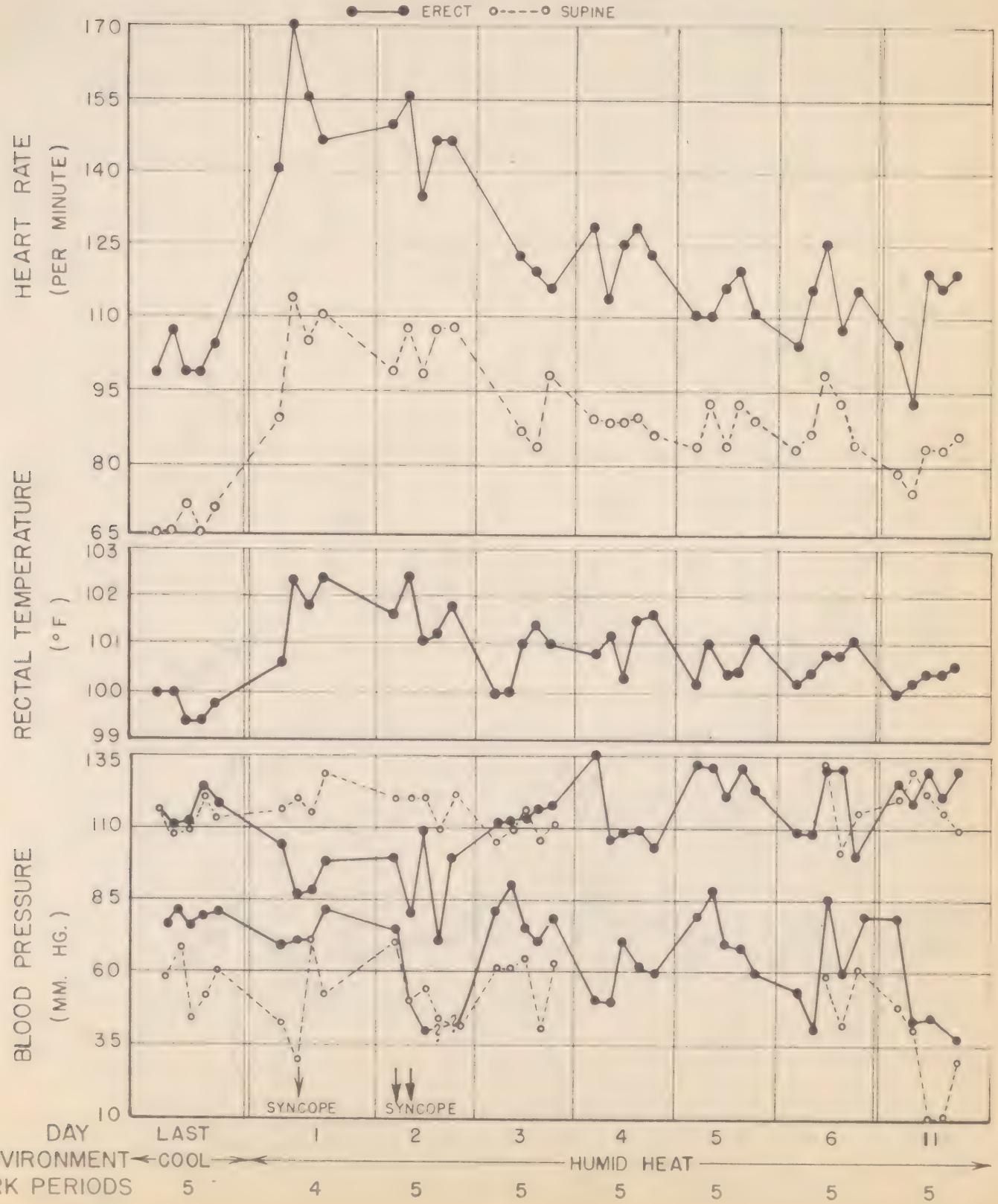


CHART - I

CHART-2

DIFFERENCES IN THE COURSE OF HEART RATE AND RECTAL TEMPERATURES IN TWO MEN, DURING ACCLIMATIZATION TO WORK IN JUNGLE HEAT

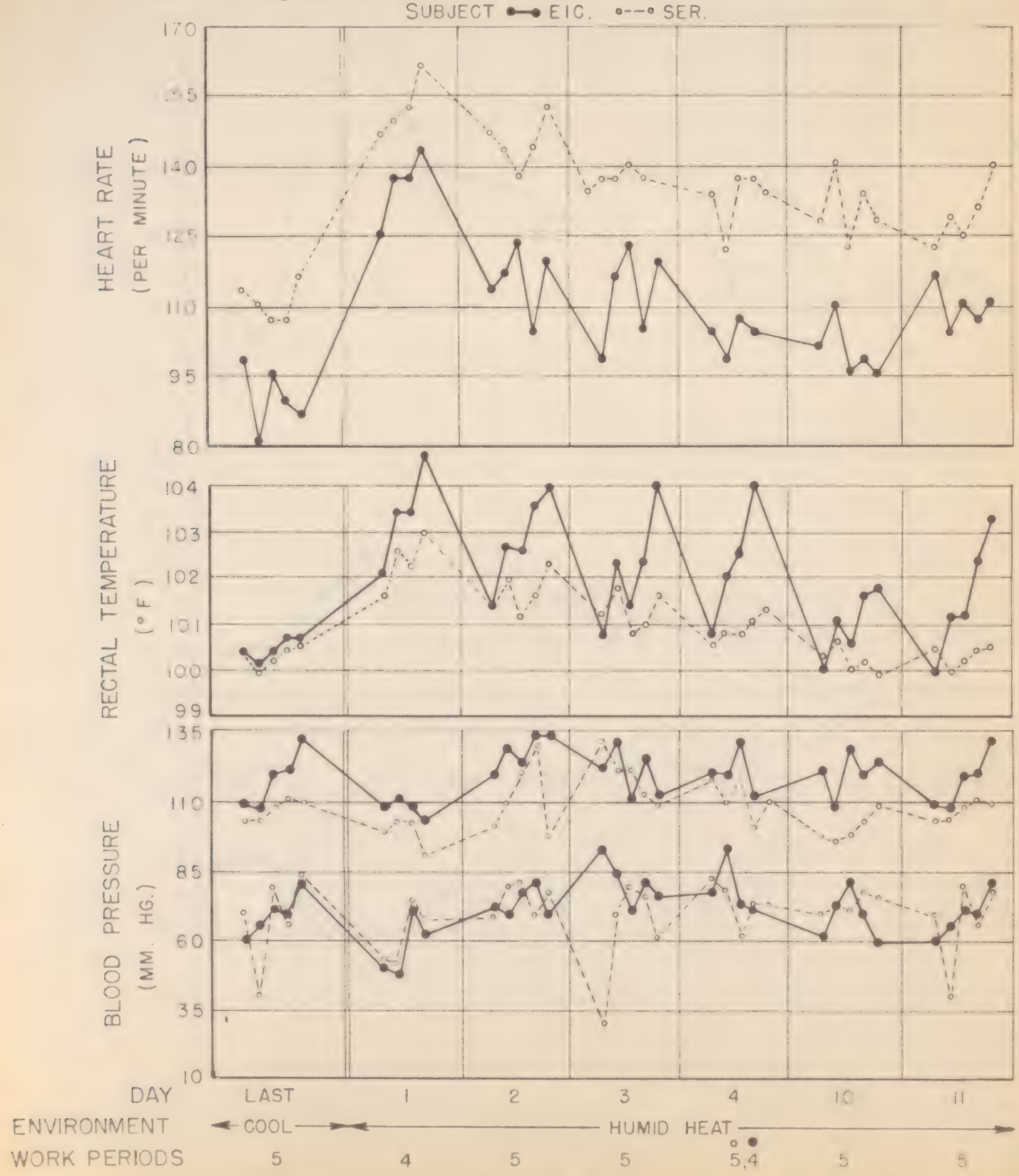
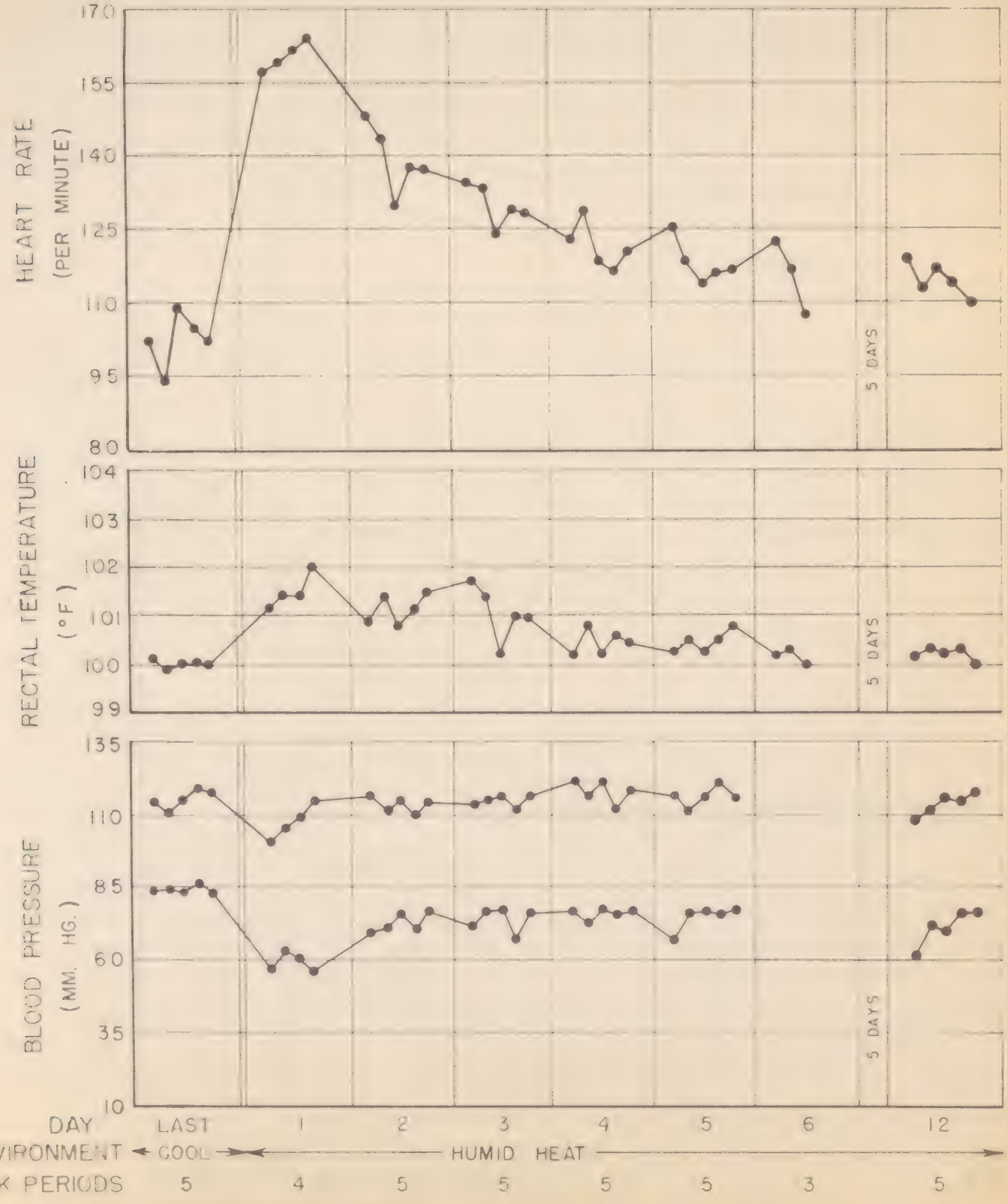


CHART-2

CHART - 3

CHANGES IN HEART RATE, RECTAL TEMPERATURE AND BLOOD PRESSURE DURING ACCLIMATIZATION TO WORK IN JUNGLE HEAT



DATA - AVERAGE FOR 14 MEN

CHART - 3

CHART-4

EFFECT OF PHYSICAL CONDITION ON ACCLIMATIZATION TO WORK IN JUNGLE HEAT

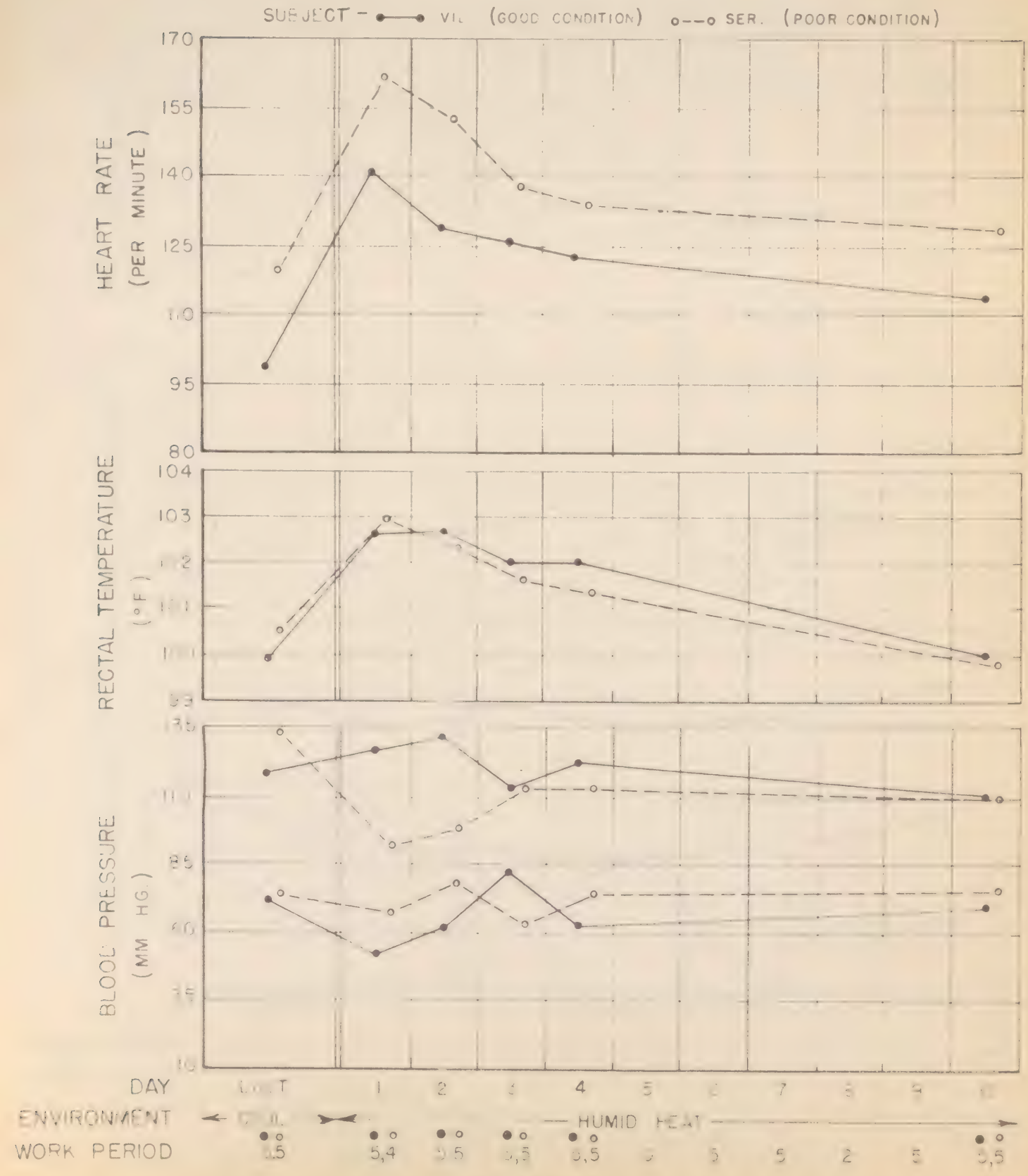


CHART-4

CHART-5

EFFECT OF PREVIOUS WORK AND ENVIRONMENT ON WORK PERFORMANCE IN JUNGLE HEAT

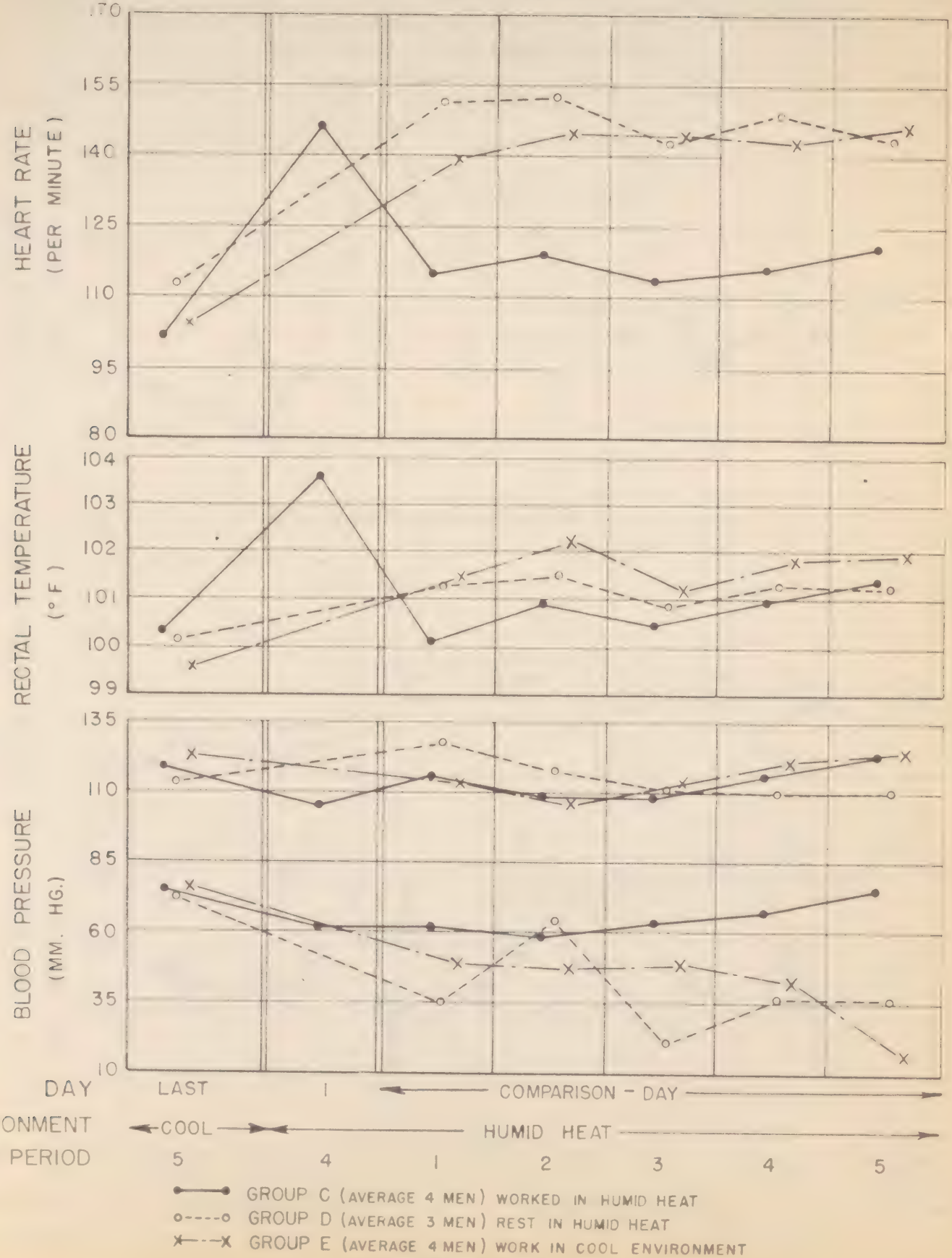


CHART-5

CHART-6

INTOLERANCE TO HEAT AND POOR WORK PERFORMANCE ON THE FIRST DAY IN JUNGLE HEAT DO NOT ALTER THE RATE OR DEGREE OF FINAL ACCLIMATIZATION

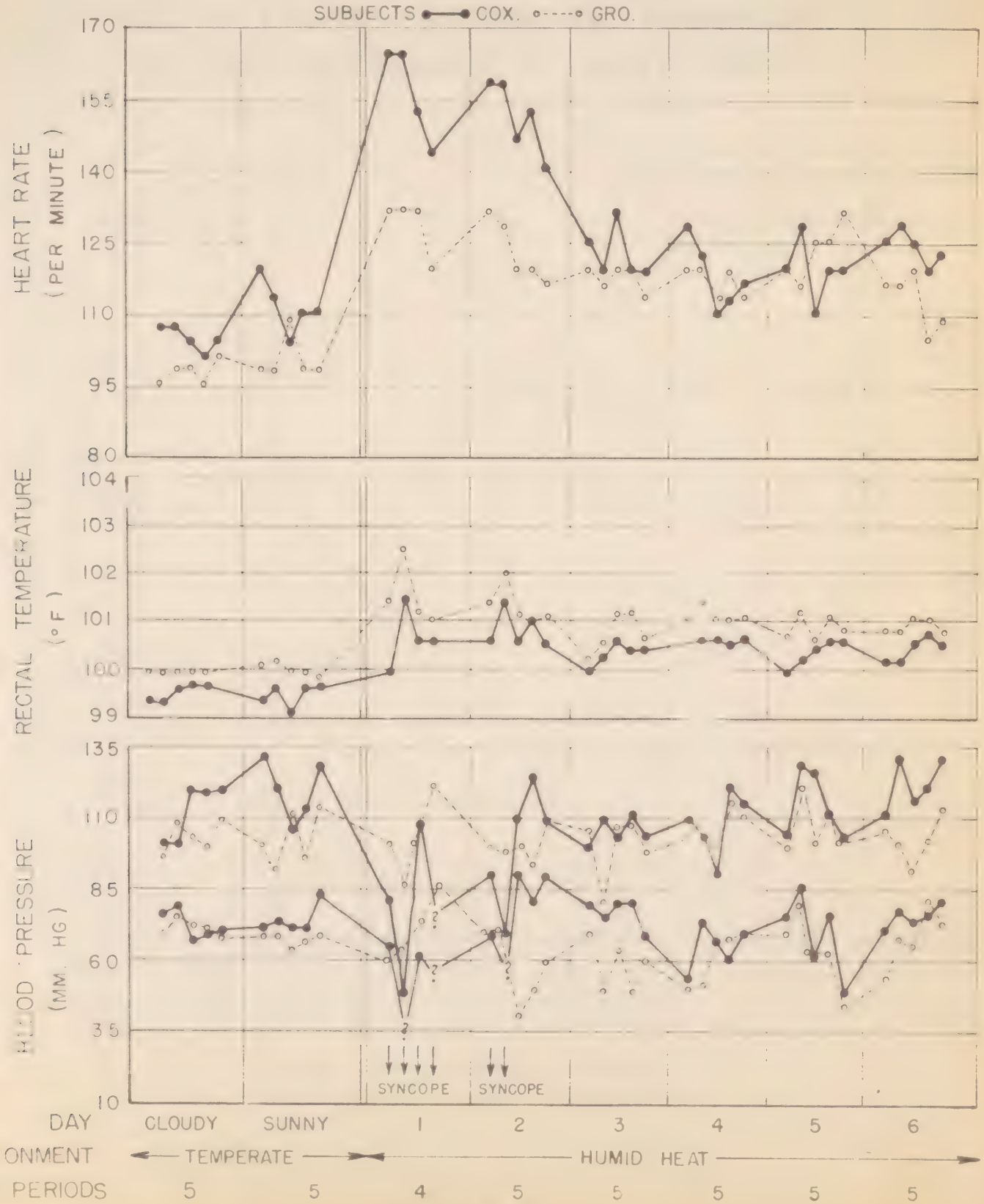


CHART-6

CHART - 7

EFFECT OF PREVIOUS ENVIRONMENTAL TEMPERATURE ON WORK PERFORMANCE IN JUNGLE HEAT

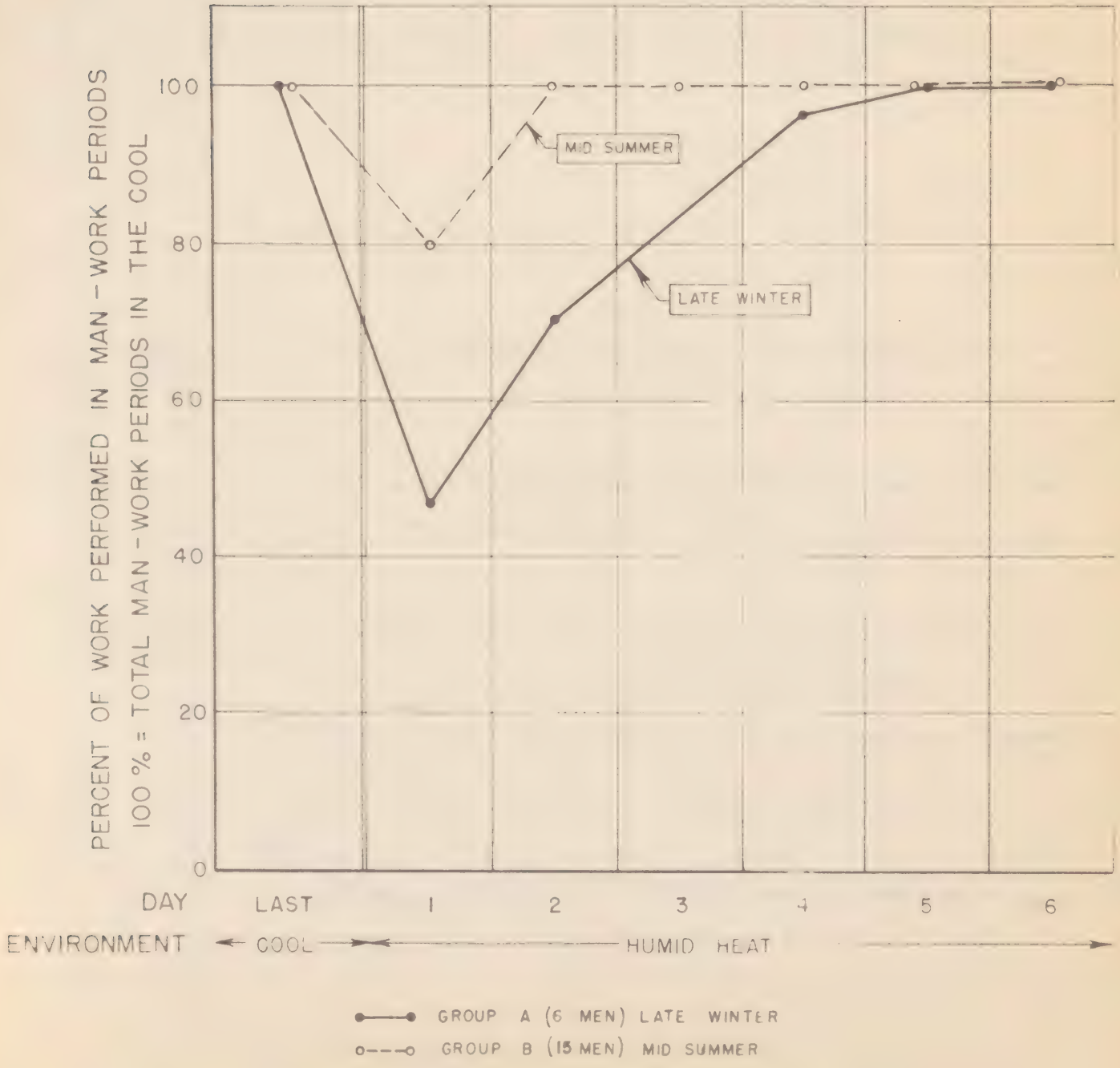


CHART - 7

CHART - 8

EFFECT OF PREVIOUS ENVIRONMENTAL TEMPERATURE ON ACCLIMATIZATION TO JUNGLE HEAT

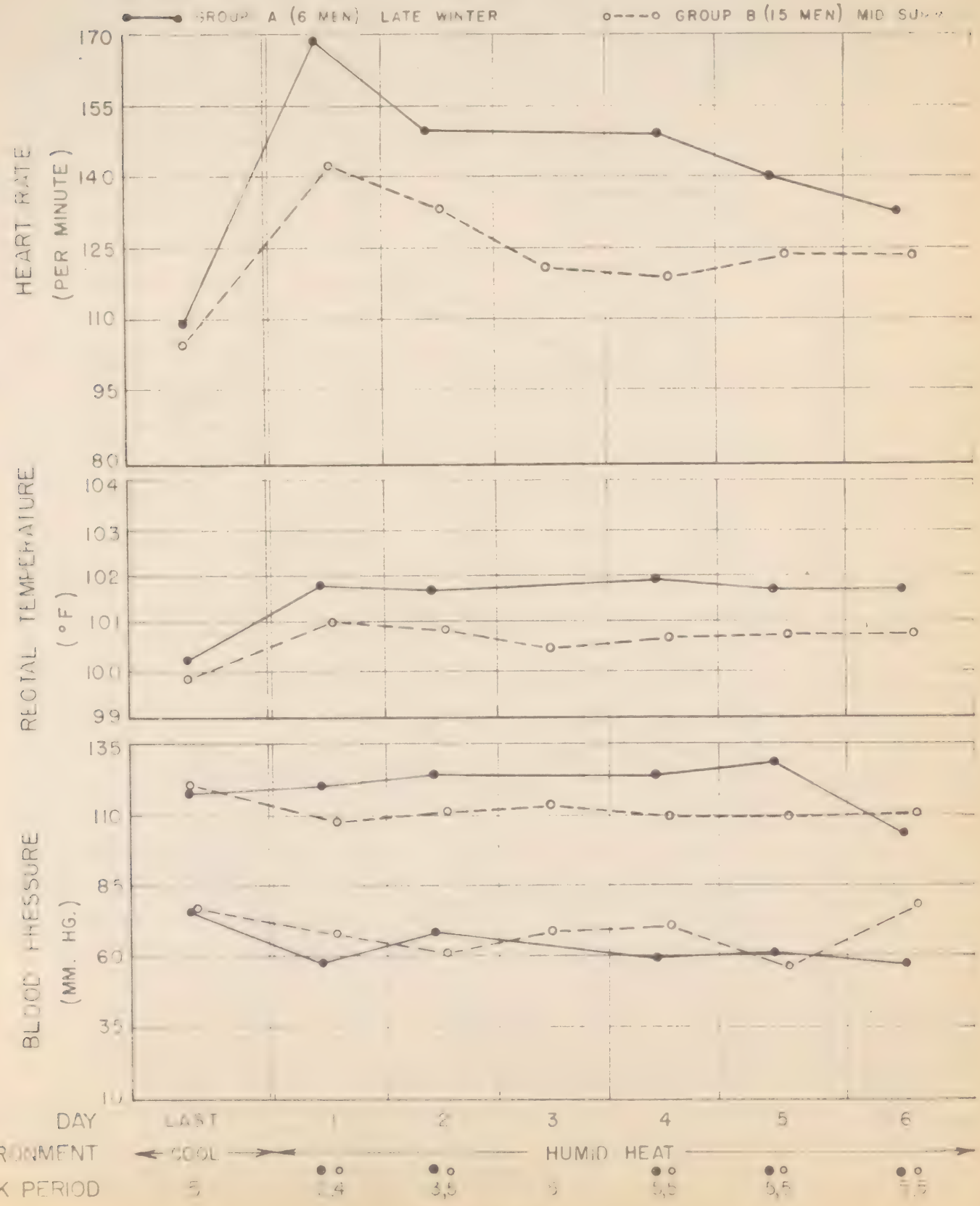


CHART - 8

CHART - 9

EFFECT OF SUBSEQUENT ENVIRONMENTAL TEMPERATURE ON RETENTION OF ACCLIMATIZATION TO JUNGLE HEAT

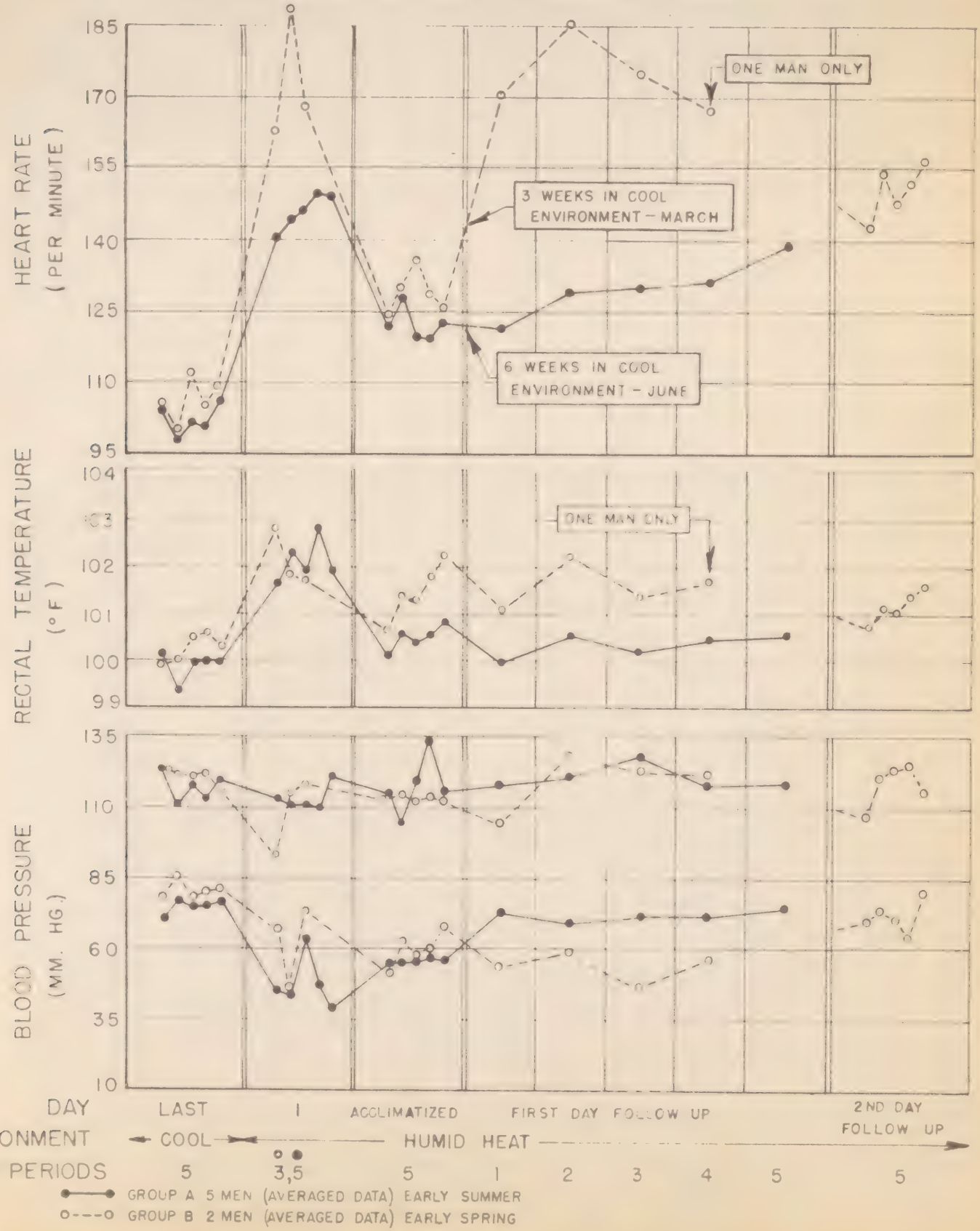


CHART - 9

CHART - 10

EFFECT OF PREVIOUS ACCLIMATIZATION TO DESERT HEAT ON WORK PERFORMANCE DURING FIRST EXPOSURE TO JUNGLE HEAT

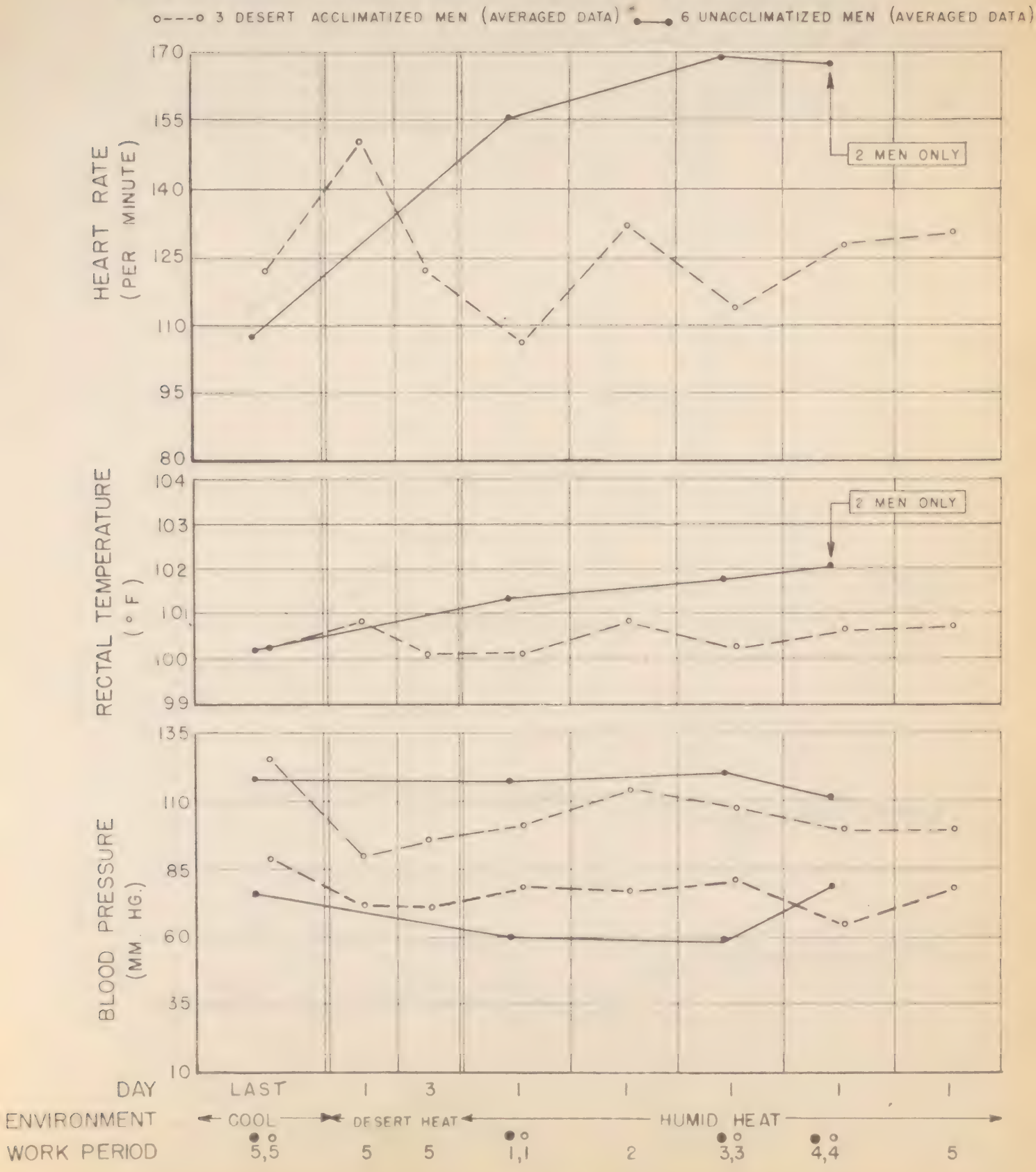


CHART - 10

CHART-11

EFFECT OF PREVIOUS ACCLIMATIZATION TO JUNGLE HEAT ON WORK PERFORMANCE DURING FIRST EXPOSURE TO DESERT HEAT

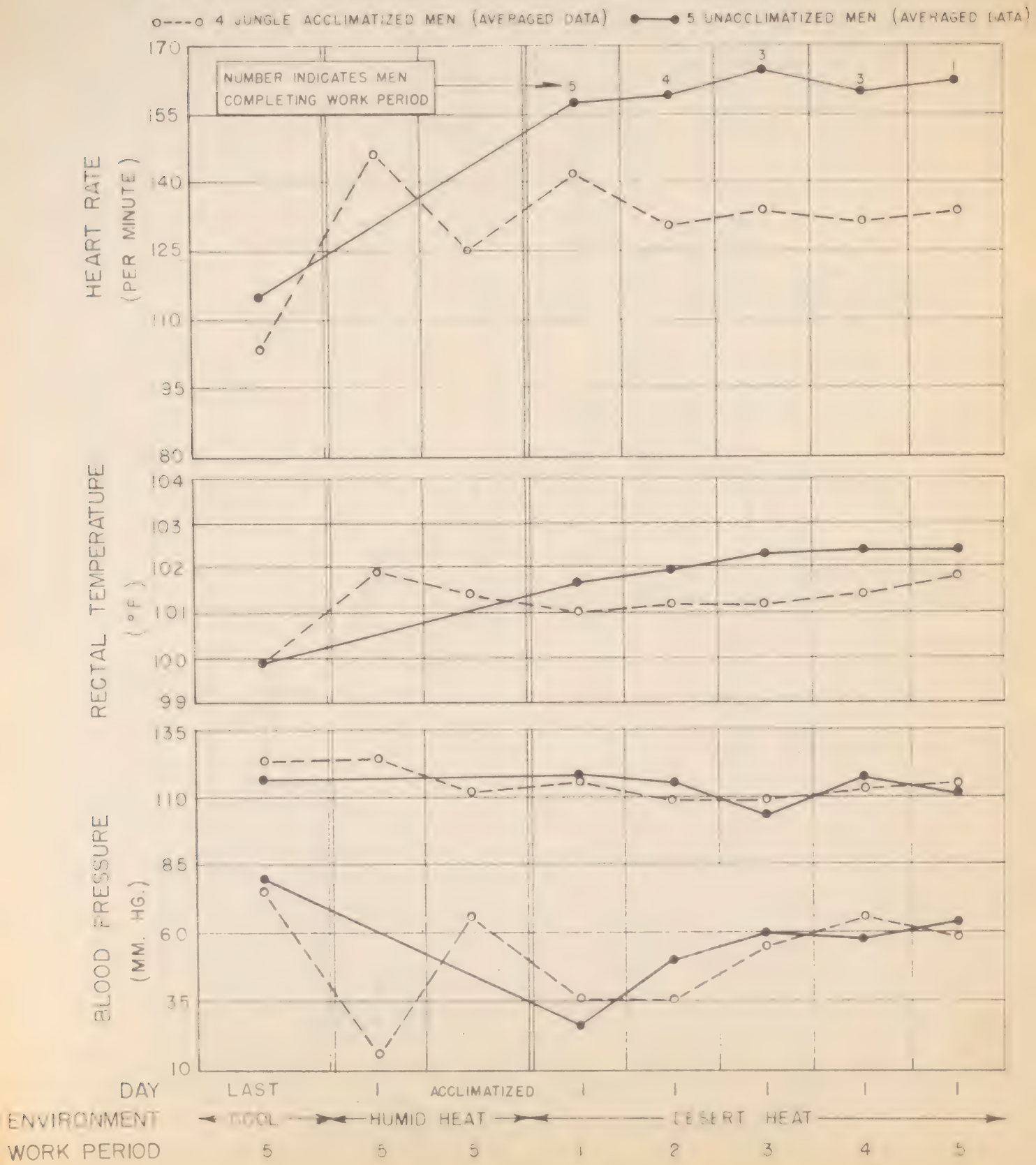


CHART-11

CHART - 12

RATE OF WEIGHT (SWEAT) LOSS OF MEN WORKING AND RESTING IN JUNGLE HEAT

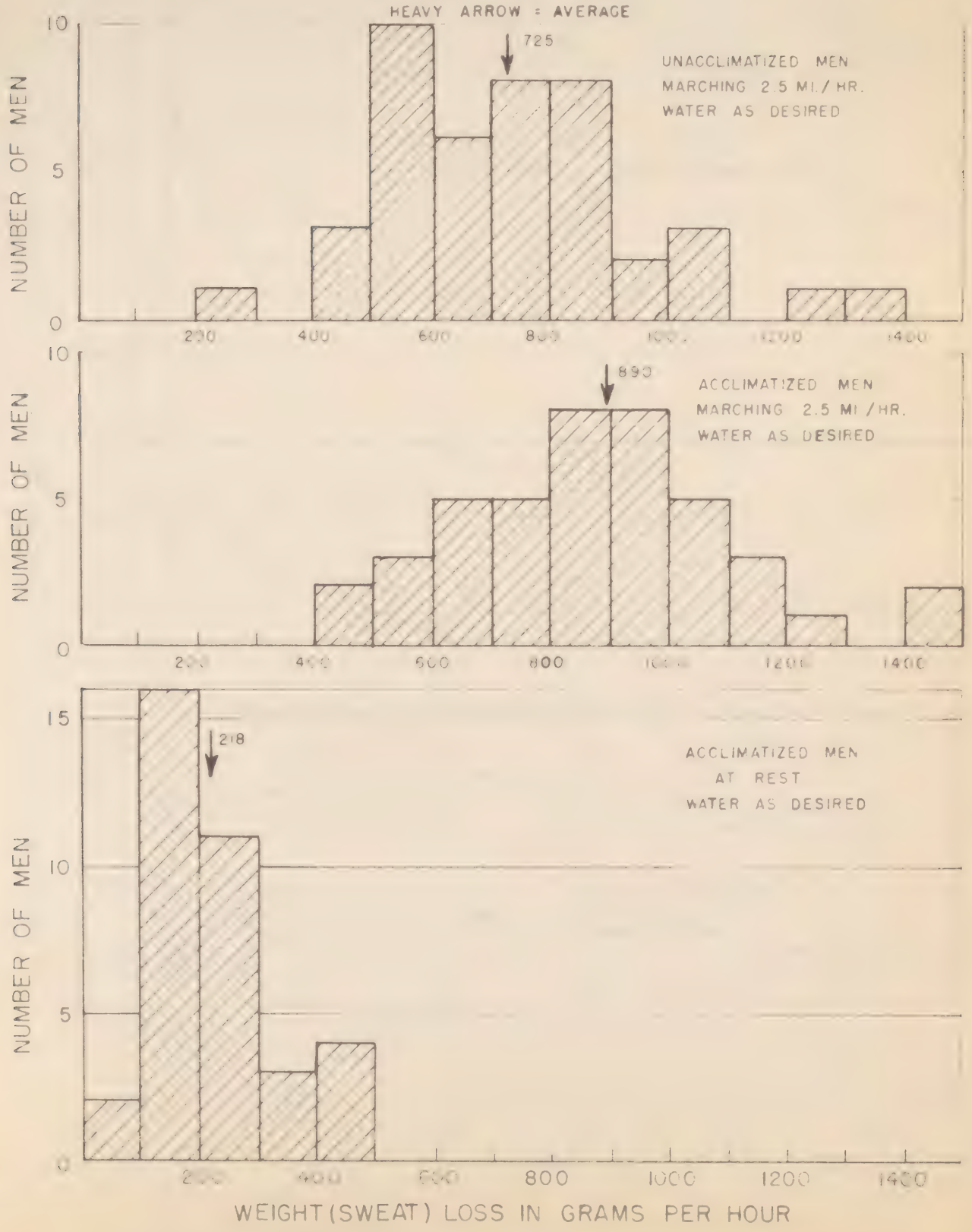


CHART - 12

CHART - 13

CHANGES IN HEART RATE, RECTAL TEMPERATURE AND BLOOD PRESSURE DURING ACCLIMATIZATION AND SUBSEQUENT DETERIORATION IN JUNGLE HEAT

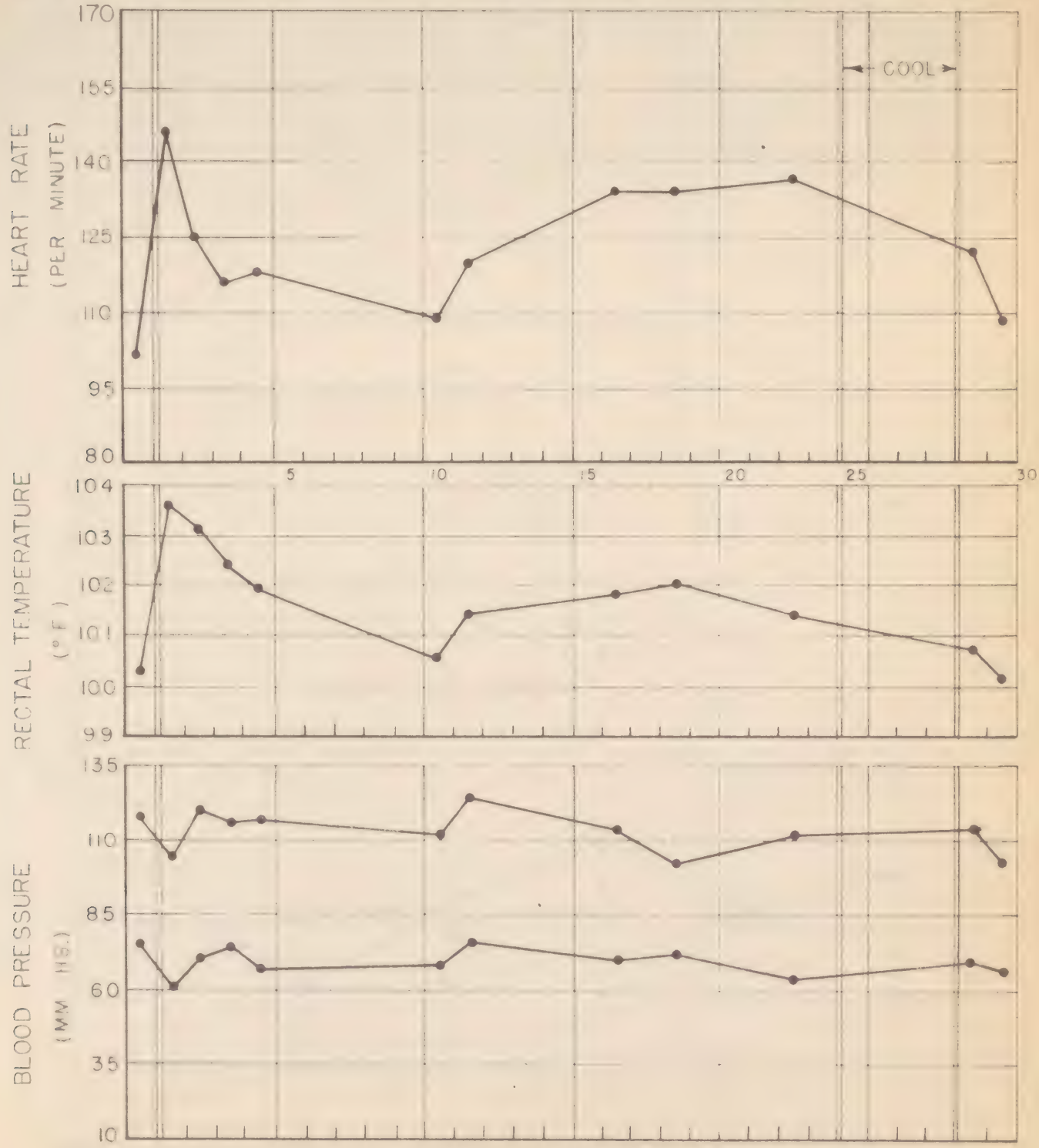
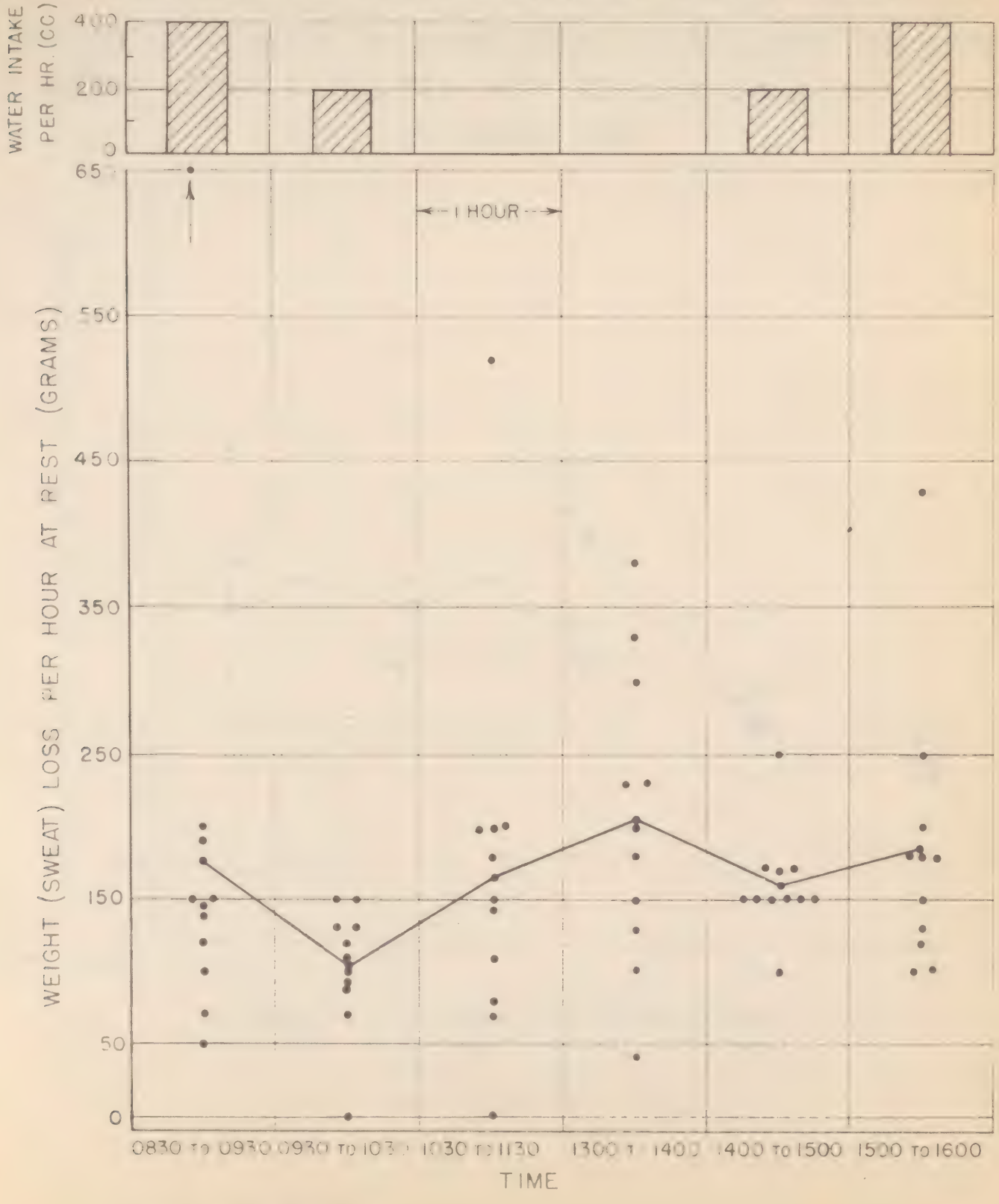


CHART - 13

CHART - 14

FAILURE OF VARIATION IN WATER INTAKE TO AFFECT THE RATE OF WEIGHT (SWEAT) LOSS PER HOUR IN ELEVEN (11) MEN RESTING IN JUNGLE HEAT

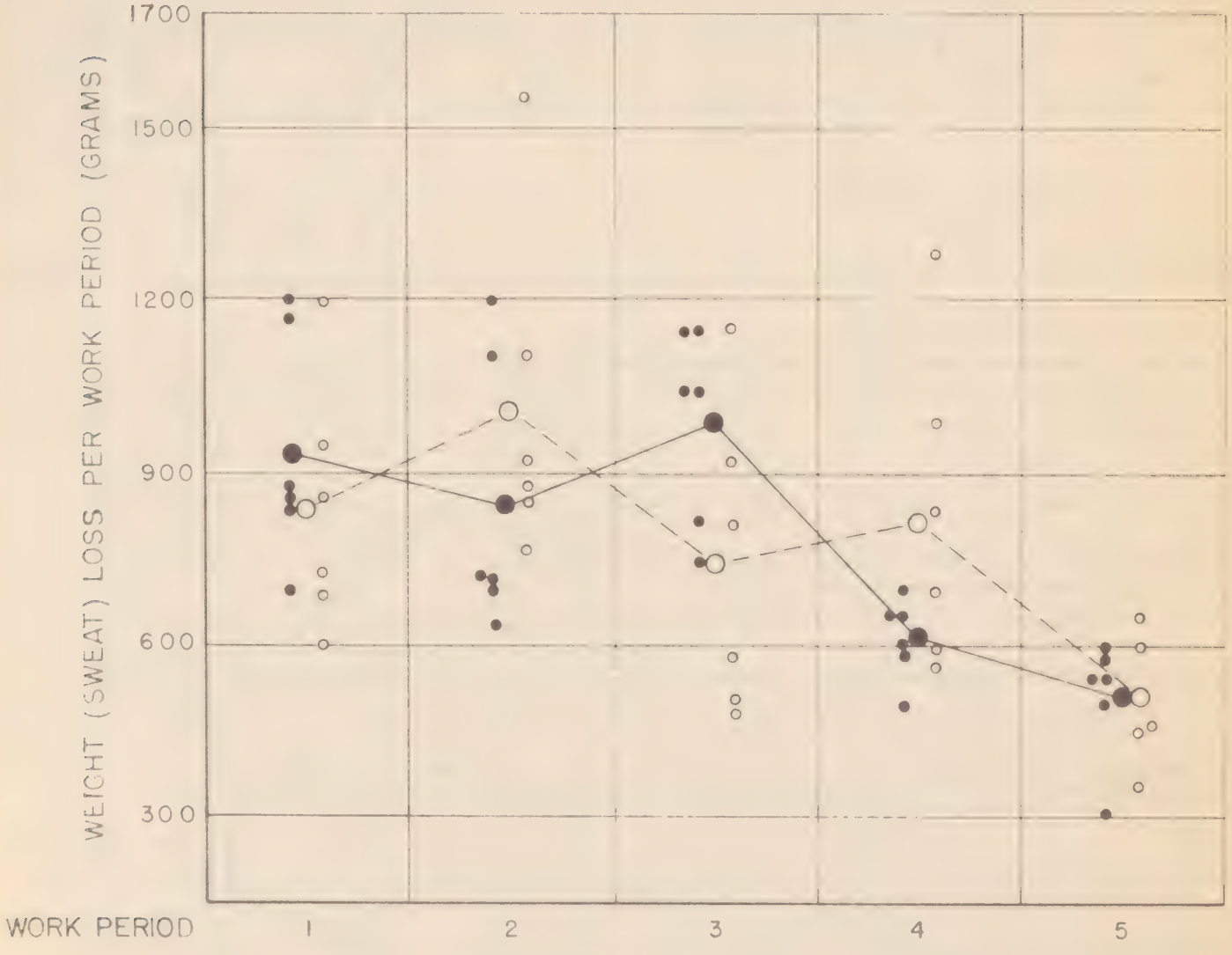


HEAVY LINE - AVERAGE
EACH DOT ONE ACCLIMATIZED MAN

CHART - 14

CHART - 15

FAILURE OF VARIATION IN WATER INTAKE TO INFLUENCE THE RATE OF WEIGHT (SWEAT) LOSS PER WORK PERIOD IN SIX (6) MEN WORKING IN JUNGLE HEAT



EACH SMALL DOT OR CIRCLE = ONE ACCLIMATIZED MAN
EACH LARGE DOT OR CIRCLE = AVERAGE OF SIX MEN
● = WATER AS DESIRED (600 CC/PERIOD)
○ = WATER RESTRICTED (150 CC/PERIOD)

CHART - 15

CHART-16

EFFECT OF RESTRICTION OF WATER INTAKE ON THE WORK PERFORMANCE OF ACCLIMATIZED MEN WORKING IN JUNGLE HEAT

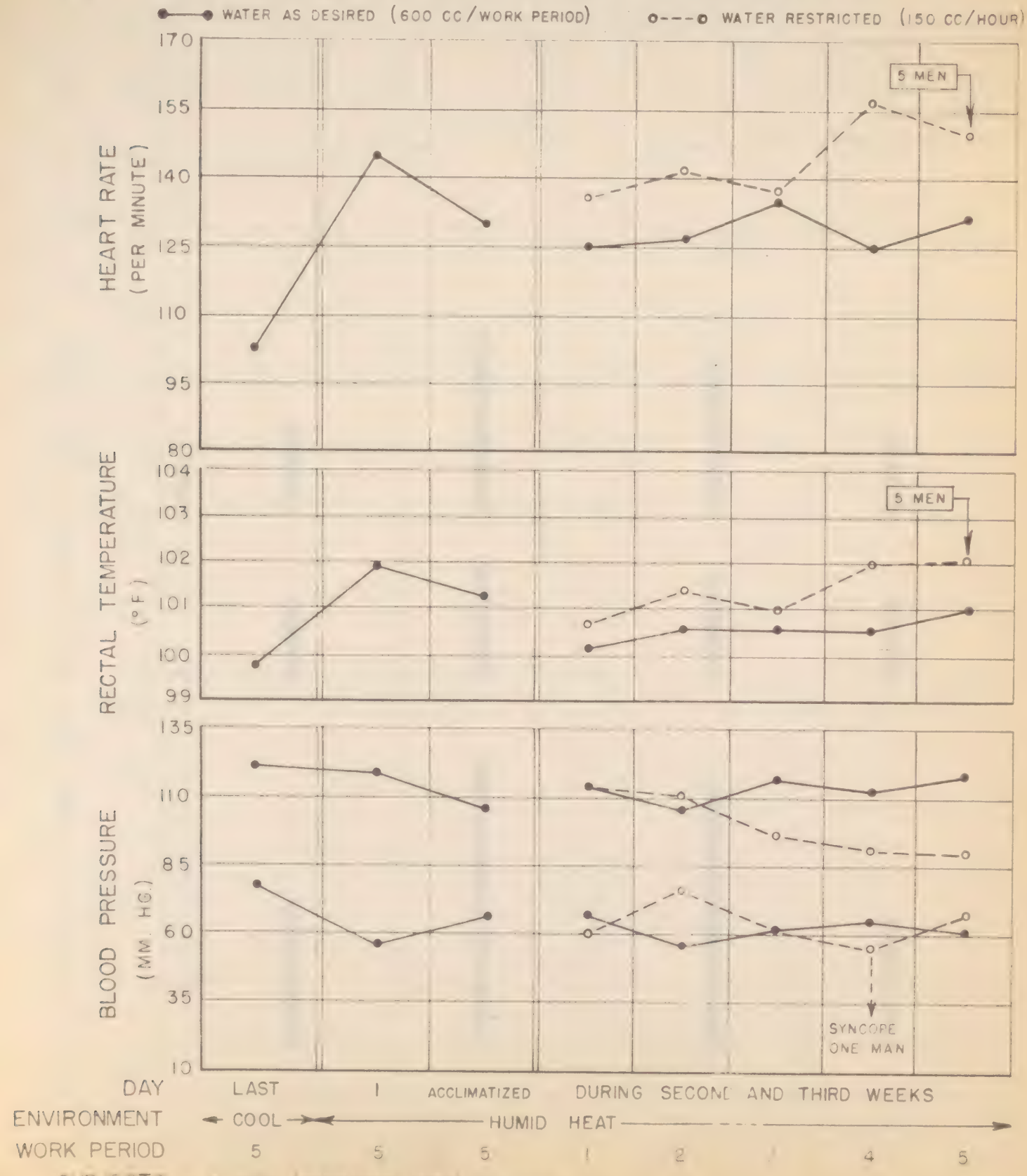
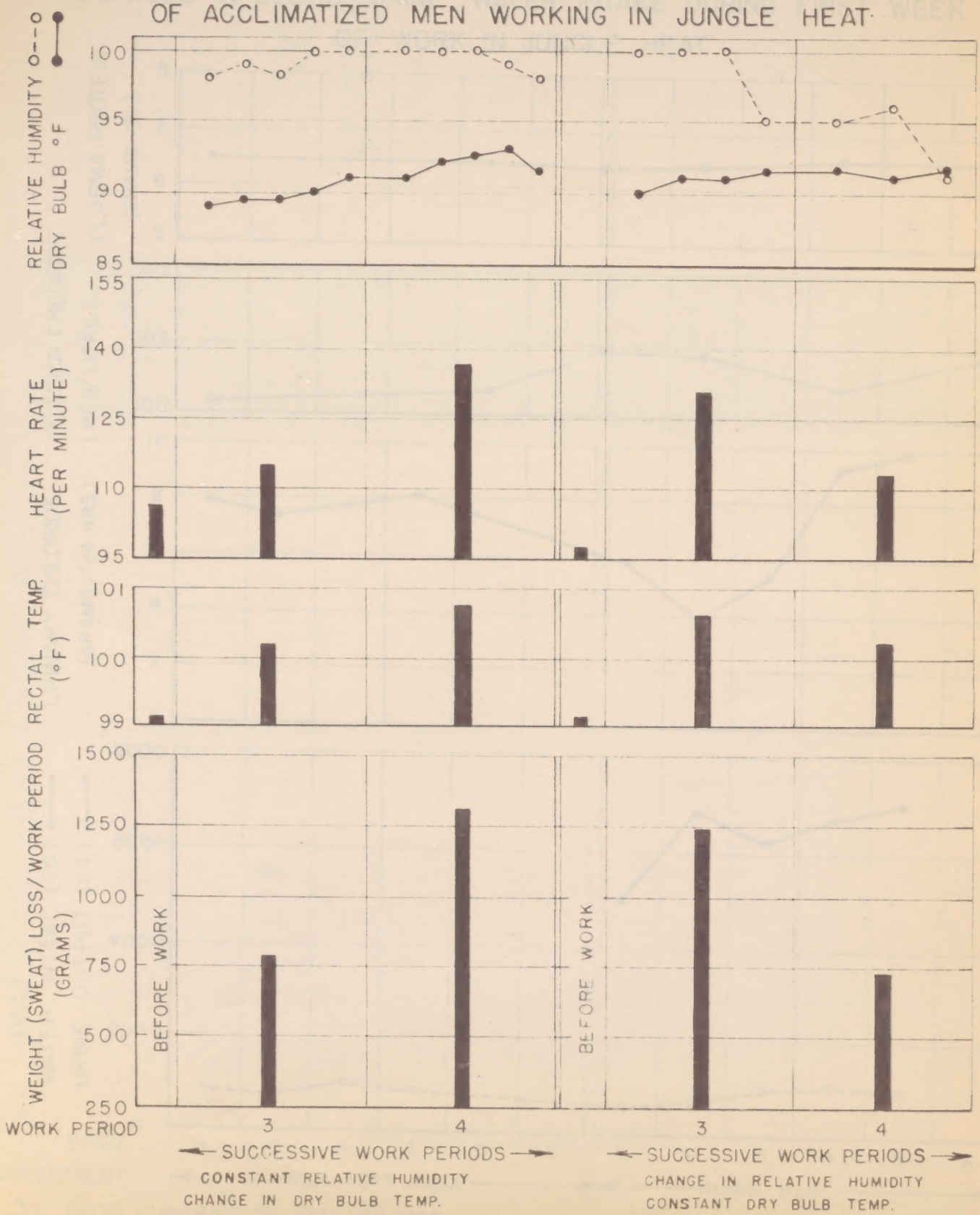


CHART-16

CHART - 17

EFFECT OF RELATIVELY SMALL CHANGES IN ENVIRONMENT ON THE HEART RATE, RECTAL TEMPERATURE, AND WEIGHT (SWEAT) LOSS OF ACCLIMATIZED MEN WORKING IN JUNGLE HEAT



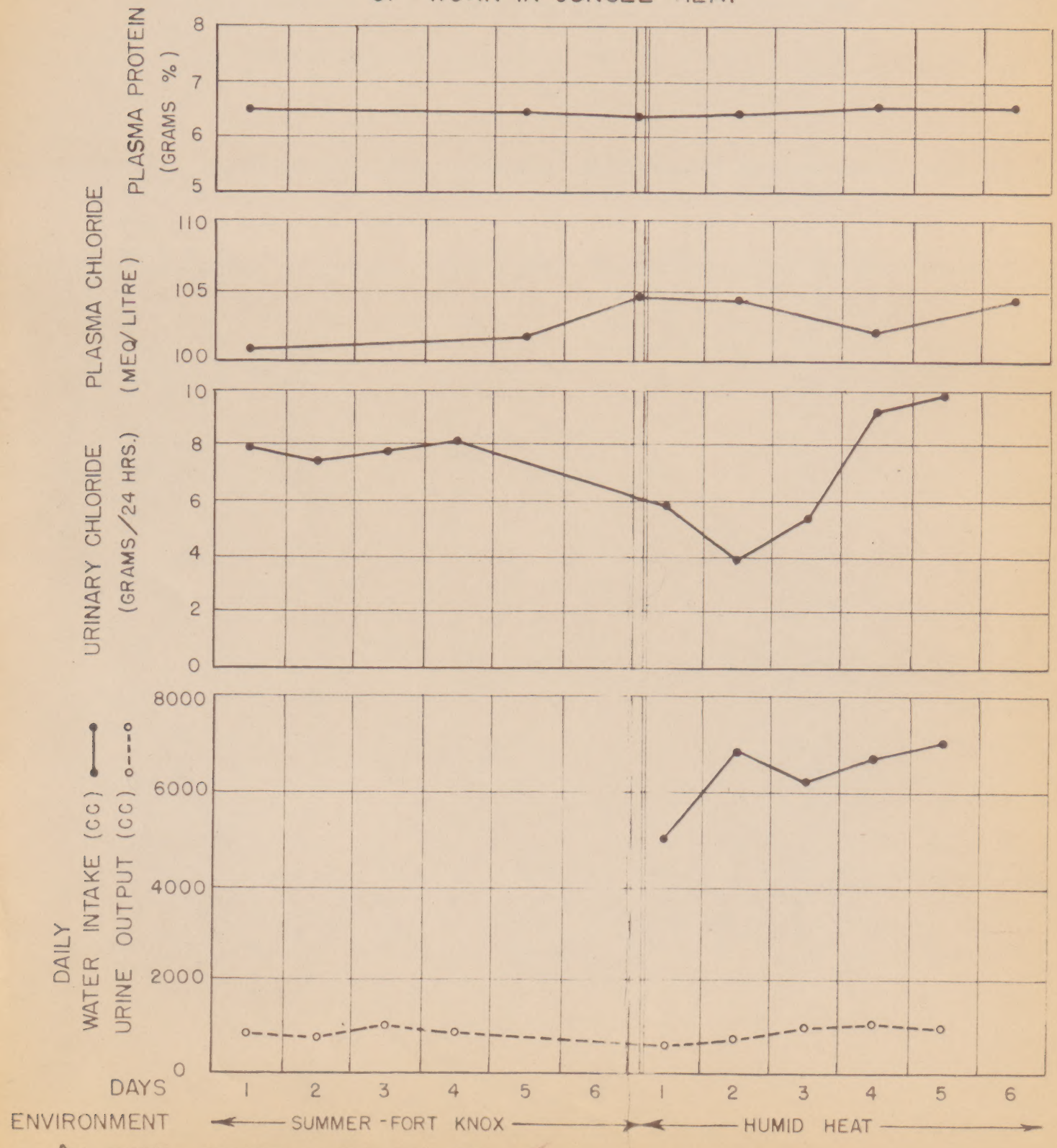
DATA = AVERAGE FOR 15 MEN

CHART - 17


RELATIVE HUMIDITY
DRY BULB °F
HEART RATE
(BEATS PER MINUTE)
WEIGHT LOSS DURING WORK PERIOD (GRAMS)
WORK PERIOD
SUCCESSIVE WORK PERIODS
CONSTANT RELATIVE HUMIDITY
CHANGE IN DRY BULB TEMP
BEFORE WORK
AFTER WORK
SUCCESSIVE WORK PERIODS
CHANGE IN RELATIVE HUMIDITY
CONSTANT DRY BULB TEMP

CHART-18

CHANGES IN BLOOD, URINE, WATER INTAKE DURING FIRST WEEK OF WORK IN JUNGLE HEAT



DATA = AVERAGE OF TEN (10) MEN

P. 38

CHART-18